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# TOWARD THE MODELING OF LAND USE CHANGE: A SPATIAL ANALYSIS USING REMOTE SENSING AND HISTORICAL DATA

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16. Abstract Research originally proposed specified the use of historical and current aerial photography to assess the parameters which determine various types of land use change, the results to provide a base for development of a simulation algorithm to predict future land use change. It was thought that such a capability would be particularly useful to regional and urban planners and would permit more accurate assessment of future land use development relative to desired urban growth and to impacts on the natural environment. The initial focus of the study is upon the conversion of land to industrial use. This approach was based upon the assumption that industrial land use is the initial stimulus to additional land use development. Residential land use development is also examined but only in a cursory manner. Commercial land use development was not examined.

It was hypothesized that the chronological observation of land use change could be shown to follow a predictable pattern and these patterns could be correlated with other statistical data to develop transition probabilities suitable for modeling purposes. A literature review and preliminary research, however, indicated a totally stochastic approach was not practical for simulating land use change and thus a more deterministic approach was adopted. The approach used assumes the determinants of the land use conversion process are found in the "market place," where land transactions among buyers and sellers occur. Only one side of the market transaction process is studied, however, namely, the purchaser's desires in securing an ideal or suitable site. The problem was to identify the ideal qualities, quantities or attributes desired in an industrial site (or housing development), and to formulate a general algorithmic statement capable of identifying potential development sites. Research procedures involved developing a list of variables previously noted in the literature to be related to site selection and streamlining the list to a set suitable for statistical testing. A sample of 157 industries which have located (or relocated) in the 16-county Knoxville metropolitan region since 1950 was selected for the industrial location analysis. Using NASA color infrared photography and Tennessee Valley Authority historical aerial photography, data were collected on the spatial characteristics of each industrial location event. These data were then subjected to factor analysis to determine the interrelations of variables, to minimize the list of


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variable needed to describe the industrial site-selection process, and to determine if the preconceived ideas concerning the factors affecting the process were valid. Seven factors accounting for 72 percent of the variance found in the original data were identified.

The 30 original variables did not group as anticipated but the factor scores suggested a logical arrangement of the remaining variables. The results indicate a zoned or designated place for industry to locate, open space suitable for industrial development, and accessibility to the site are the three most important considerations in industrial site-selection decisions. Any algorithm intended to simulate industrial land use conversion should be constructed with these parameters as major components.

Building upon the experience in the analysis of industrial land use change, a sample of 50 residential development events occurring since 1966 was selected for further analysis of metropolitan land use change. Again using the NASA and TVA aerial photography, the spatial characteristics of each residential development event were reconstructed and data collected. It was found that the 33 variables utilized in the factor analysis could be reduced to eight factors accounting for 75 percent of the original variance.

The factor results of the residential land use analysis were not easily interpreted. The original 33 variables, however, were reduced to 19 and the relative importance of each was indicated. The results suggest that residential development is primarily a function of municipal service availability, positive compatibility with neighboring land uses, proximity to commercial services, and accessibility to major highways. Other important considerations are adjacency to existing residential development, low density of adjacent development, and proximity to collector highways.

Several conclusions of the analysis of industrial and residential land use development are noted. Firstly, the empirical and statistical approaches utilized in this study demonstrated a methodology to assess the qualitative and quantitative attributes important in land conversion processes. Secondly, the factor analytic procedure produced results which were logical and in agreement with existing theory, and permitted identification of the most important variables affecting land use change.

The results also indicated, however, that more study is needed before a satisfactory simulation algorithm may be constructed. In subsequent research, discriminant analysis and canonical correlation are suggested as promising analytical tools to uncover hidden interrelationships of variables and identify more completely the factors affecting land use change.

Finally, it is important to note that most of the variables identified as significant to the land use development processes are amenable to measurement from high quality, color aerial photography. This represents a means of acquiring such data which are within the economic capabilities of most urban and regional planning groups.

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# I. INTRODUCTION

## Problem Background

Most urban and regional planners seek to answer the question, "What would happen if...?" The answer is not simply determined. In our complex society, it is difficult for the decision maker to anticipate or visualize the many possible ramifications of a specific option for urban or regional development. Ultimately the decision to develop or not develop is based upon a best guess as to the future consequences of the decision. If, however, we can specify the mechanisms of regional development and represent them symbolically as a set of equations, the computer can approximate through simulation, years of regional growth in a matter of minutes. Such a capability might reduce dependence upon so-called "seat of the pants" planning. Before we can accurately simulate regional growth, however, the development processes must first be defined and understood, and by observing the limited success of previous land use modeling efforts we become acutely aware than we do not sufficiently understand them.[1] This research effort focuses specifically upon acquiring an understanding of these land use development processes.

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[1]Models should not be judged simply on a success-failure basis but rather in terms of the models' ability to answer questions about the real world. In the past, some models have been more successful than others. For a review of previous modeling efforts one should consult: Ira S. Lowry, *Seven Models of Urban Development: A Structural Comparison* (Santa Monica, California: RAND Corporation, 1967); B. W. Mar and W. T. Newell, *Assessment of Selected RANN Environmental Modeling Efforts*. A report prepared for the Environmental Systems and Resources Division, National Science Foundation (Seattle: University of Washington, June 1973); and O. Stradel and B. G. Hutchinson, *Notes for a Short Course on Practical Applications of Regional Development Models* (Waterloo, Ontario: University of Waterloo, The Transport Group, Department of Civil Engineering, November 1971).

Land use change or growth is normally stimulated or brought about by certain "triggering" events or mechanisms and afterward may "feed" upon itself. Many early land use modeling efforts assumed the "triggering" mechanism to be brought about by the location of new industry. We now recognize that other stimulating mechanisms such as improvements in transportation or expanding demand for personal services also may prompt regional growth.[2]

Brown et al. recognized "the critical importance of industrial location. . .yet land-use modelers have devoted surprisingly little effort to analyzing the determinants of industrial location."[3] Only a few research efforts have made serious attempts to model the basic determinants of industrial location choices and "for the most part these attempts have been quite limited and crude."[4] This research is predicated upon the assumption that new industry is the major stimulus for urban and regional growth and thus deserves initial consideration in the study of land-use development processes. A secondary emphasis is upon the analysis of residential land-use development.

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[2]Homer Hoyt was among the first urban economists to study the growth and development of urban land. His primary axiom was that "no city could grow by taking in its own wash." Homer Hoyt, *The Structure and Growth of Residential Neighborhoods in American Cities* (Washington, D.C.: U.S. Government Printing Office, 1939).

[3]James H. Brown and others, *Empirical Models of Urban Land Use: Suggestions on Research Objectives and Organizations*, Exploratory Report 6 (New York: Columbia University Press, 1972), p. 82.

[4]Ibid.

## Statement of Problem

An initial requisite of any model purporting to replicate and predict land use development is the identification of those land parcels having the greatest probability to change to a specific land use. In order to do so it is necessary to construct an algorithm which calculates the suitability of some land parcel for a specific land use. The primary objective of this research effort is to develop the capability to identify land parcels having the highest probability of converting to industrial or residential use. More specifically this research attempts to identify and measure the importance of <u>intrinsic site characteristics</u> which appear to control the conversion of land to industrial and residential use within the 16-county, Knoxville metropolitan region and to specify the mathematical form of a simulation algorithm capable of identifying potential industrial and residential sites.

## Problem Operationalization

<u>Intrinsic site characteristics</u> refer to the qualities possessed by some land parcel that identify its suitability for a specific land use. In the case of industrial land use, examples of some of the attributes which should be examined are: proximity to rail service; access to nearby highways; site preparation costs; availability of city services; or whether the site is within a developed industrial park. In the case of residential land use, many attributes may be the same but the importance of each will change. Measuring the importance of these attributes is often difficult.

The following is a list of factors that are often identified as affecting industrial land use choices:

> Site Preparation Costs--The cost of converting rural or open land to manufacturing use. Matters which might be taken into account are foundation conditions, drainage conditions, slope of the land, and type of vegetation cover. This factor would not include the purchase price of the land.
>
> Market Price of Land--The per-acre cost of land to the manufacturer who wishes to build a new plant or expand his existing plant. This would include property taxes but not necessarily taxes on improvements to the property.
>
> Proximity to Suitable Labor Force--The number of suitable workers within easy access of the site.
>
> Transportation Accessibility--The ease with which people or materials can be moved from the plant site to roads, railroads, airports, or waterways. In this factor, the concern is with the linkage between the plant and major transportation facilities within the immediate area.
>
> Utilities--The kinds and quality of utilities available at the potential plant site. Some utilities which might be considered are water, sewer, and gas.
>
> Compatibility with Existing Land Uses--The compatibility of general manufacturing activity with other existing land uses adjacent to the potential site.
>
> Neighborhood or Community Attractiveness and Amenities--The condition and density of dwelling units and business establishments in the immediate area of the plant site, and proximity to hospitals, schools, parks, and churches.
>
> Industrial Park Space--The availability of suitable buildings or land in an industrial park. The appearance of the park and the quality of services produced are some of the considerations to be examined.

This list was compiled from both a review of literature and preliminary study. A similar list might be compiled for residential land use. Particular combinations of variables are not unique but simply represent logical groupings based upon a literature review. For the purpose of this analysis, the list serves as a beginning point to be refined after further study.

Each factor posited is considered to reflect an information unit which may be evaluted in the selection of industrial sites at the intra-urban scale. By combining these factors or indexes it is possible to develop an aggregate measure of the suitability of a site for industrial use. Before doing so, however, a weight should be attached to each index to reflect its relative importance in the location decision. A general mathematical form for a site selection algorithm might be as follows:

$$LUS_{\ell} = \sum_{i=1}^{N} W_{i,\ell}\, I_{i,\ell} \;;$$

where LUS = Attractiveness score for land use category $\ell$ (in this case $\ell$ = industrial land use),

N = Number of indices,

$W_{i,\ell}$ = Index weight for the *ith* index and the *$\ell$th* land use category, and

$I_{i,\ell}$ = *ith* index for the *$\ell$th* land use category.[5]

In modeling land use development attractiveness scores would be utilized in the following manner:[6] Projected industry growth provided via a socioeconomic model are distributed initially to various subregions through a subregional allocation algorithm. Industrial,

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[5]Oak Ridge National Laboratory, *Regional Environmental System Analysis,* A Research Proposal Submitted to the National Science Foundation, Research Applied to National Needs (RANN) Feb. 1, 1973, p. 9.

[6]Land use models are constantly evolving and thus one can only speak of the framework of the model in a hypothetical manner. This may or may not become the structure of the model and represents only a tentative view as to the operating manner of the model. More detail may be found in A. H. Voelker, *A. Cell-Based Land Use Model,* ORNL/RUS-16, Oak Ridge National Laboratory (1976).

residential, and commercial expansion within the subregion are distributed to available land parcels on the basis of attractiveness scores calculated in the above manner. The availability of various land parcels is determined from knowledge of the probability that specific land parcels will be offered for consumption.[7]

The land use model as presently conceptualized is perhaps best characterized as a hybrid deterministic-stochastic model. The suitability of various land parcels for a specific land use is calculated using the land use scores which are deterministically derived. Projected growth in land use is then awarded in a stochastic manner to various land parcels on the basis of the land use scores ($LUS_\ell$). As the land use conversion processes are better understood, deterministic procedures will be substituted for simulation-stochastic procedures.

## Problem Rationale

It has been noted that "urban spatial organization is the outcome of a process which allocates activities to sites. In our society,

[7]The assumption that all land is potentially available is not a valid premise in that not all property owners are willing to sell property. Cadastral data and ownership characteristics necessary to develop a site-availability algorithm are not readily available and, therefore, very few land use models have included this consideration. The sociopolitical modeling team at Oak Ridge National Laboratory has studied the methods to identify land parcels which may be available for various land use activities. See: Osbin L. Ervin and Charles R. Meyers, Jr., *The Utilization of Local Opinion on Land Use Simulation Modeling: A Delphi Approach* (Oak Ridge, Tennessee: Oak Ridge National Laboratory, ORNL-NSF Environmental Program, 1973). Olaf Helmar, *The Delphi Method for Systemizing Judgments about the Future* (Los Angeles: University of California, April 1966).

the process is mainly one of transactions between owners of real estate and those who wish to rent or purchase space for homes and businesses."[8] The market process of "transactions between willing buyers and willing sellers determines the spatial organization of urban activities . . ." and thus should dictate the methodological structure of land use models.[9]

The market place however is not perfect. Individual land speculation, family or corporate property gifts, over-building by contractors, land use planners over-estimating demand, governments exercising property rights, the tendency for land uses to remain intact and the perpetuation of mistakes rather than corrections, all spoil the simple modeling of market transactions. However, after investigating numerous approaches toward modeling land use development, Lowry notes the market place remains the most viable way to approach the simulation of urban development.[10] The site-selection factors sought by this study are those which the developer considers in selecting an adequate industrial or residential site. Seller considerations and other market perturbations are not examined at this time.

The results of this research effort are intended to integrate with a "holistic" environmental-land use model to be developed in the future. The motivation which stimulated this research problem, however, was the

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[8]John P. Crecine, *Computer Simulation in Urban Research* (Santa Monica, California: The RAND Corporation, 1967), p. 2.

[9]Ira S. Lowry, *Seven Models of Urban Development: A Structural Comparison* (Santa Monica, California: The RAND Corporation, 1967), p. 5.

[10]Ibid.

desire to understand the land use development process. Understanding and modeling land use change involves lengthy study. Because of the short period allotted for this research, the decision was made to focus initially upon understanding the processes of land conversion in the hope that by expanding the understanding of the process, rigor could be added to the eventual development of a comprehensive land use model.

## Data Acquisition

Finally, a unique characteristic of this study is the use of historical and current aerial photography to collect and analyze measurements of variables possibly related to land use site selection processes. In itself, the utilization of aerial photography to study land use development is not new; however, its use to structure a land use modeling algorithm is different from most previous studies.

Obviously aerial photography should not be considered a sole source of data for land use analysis. Most planning agencies maintain files pertaining to the location of utilities services, industrial park locations, transportation services, and neighborhood conditions which could augment data provided by aerial photography. For this study much of these data have been compiled, digitized, and stored by the Computer Sciences Division at Oak Ridge National Laboratory and were utilized to supplement data collected from the aerial photography. By combining these data with data derived from the aerial photography, a more thorough analysis of land use development processes is possible.

# II. THEORETICAL AND EMPIRICAL STUDIES RELEVANT TO INDUSTRIAL AND RESIDENTIAL SITE-SELECTION

The purpose of this chapter is to relate to this research effort ideas expressed within selected theoretical and empirical studies and to provide a base for developing a tentative list of variables for the industrial and residential location analysis. Discussion of some works may be abbreviated depending upon their relevance to site-selection processes. Theoretical works involving classical location theory are dis-dussed first, followed by a discussion of empirical studies of industrial and residential location factors. The remaining sections discuss approaches utilized in other land use models.

## Selected Theoretical Works

The present location of specific land uses in an intrametropolitan area is the result of a complex interaction of variables that can best be understood through empirical examination of historical events. Classical location theory, however, abstracts from reality by use of the principle *ceteris paribus* where one or two variables are permitted to vary while all other variables are held constant. The works of Von Thünen and Weber represent classical contributions to location theory and were examined first is this study. More recent theoretical works follow.

Der Isolierte Staat[1]

Von Thünen's works dealt with a hypothetical agricultural land use system whereby transportation costs and economic rent were used to explain the location of specific types of agricultural production placed concentrically around a market center. In a similar manner, one might expect industrial, commercial, and residential land uses to arrange concentrically around an urban center (Fig. 1). For a specific land use the utility (accessibility) derived from any location would decline with increasing distance from the CBD as in (a). This, of course, assumes that the CBD is the most accessible point within the urban area. The optimal price one would pay for utility or accessibility is illustrated in (b). Cost incurred in obtaining utility (Y) is represented by the area (XYZA) but the profit to be derived at utility (Y) is (ABCZ).[2] This profit is similar to the land rent of Von Thünen's agricultural model. Thus, rent for various land uses can be expressed as a function of distance from the CBD as in (c). Based upon the comparative bid-rent capabilities of each land use, one would expect ($RR_1$) to represent the rent function for residential land use, ($QQ_1$) for wholesaling and industry use, and ($PP_1$) for commercial and service activities. The intersections at Y and Z would form the boundaries between the various land uses.[3]

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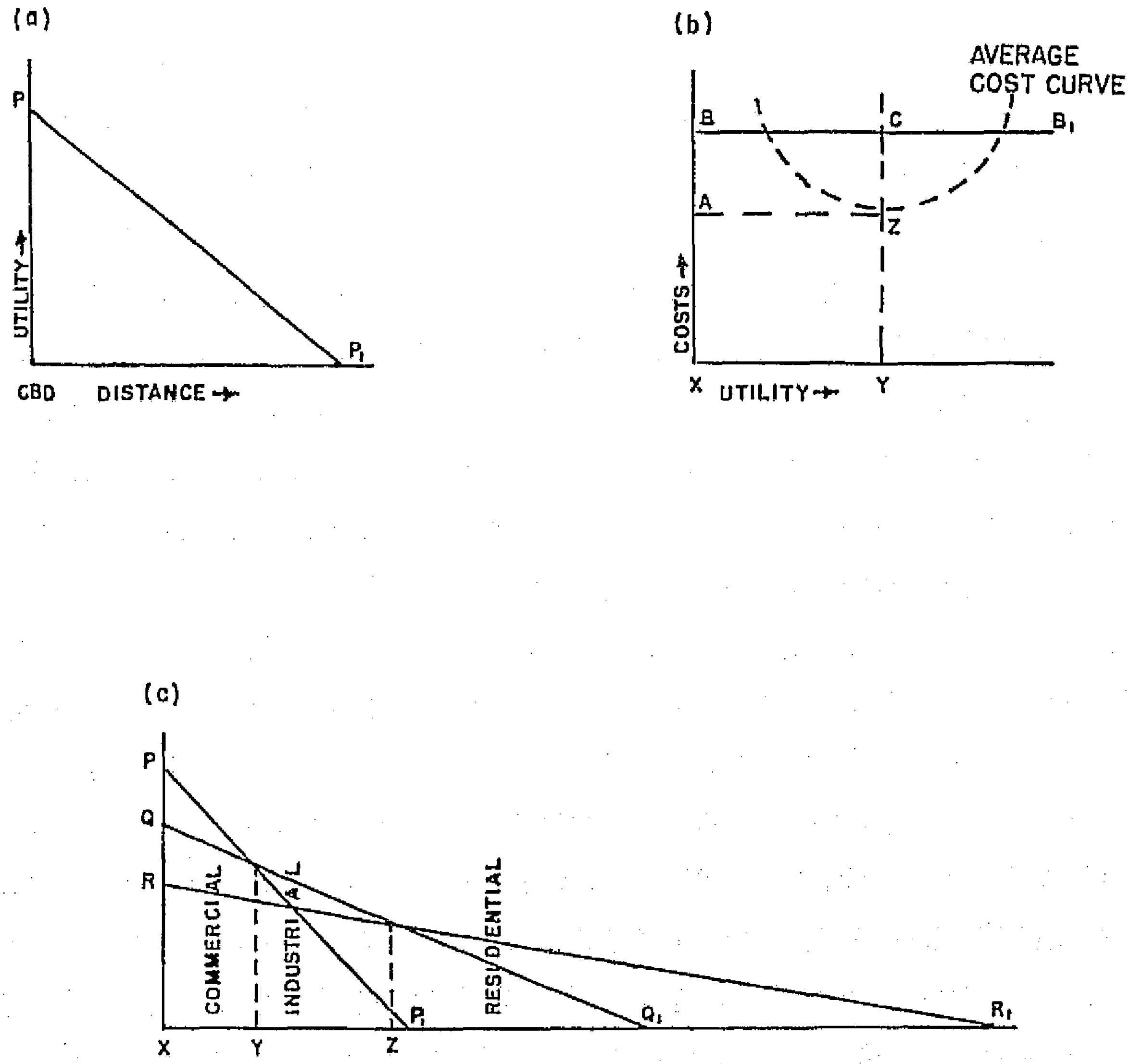
[1] Johann Heinrich Von Thünen, *Der Isolierte Staat in Beziehung Auf Landwirtschaft Und Nationalökonomies* (Berlin: Schumacher-Zarchin, 1875) in K. W. Kapp and L. L. Kapp, Eds., *Readings in Economics* (New York: Barnes and Noble, 1949).

[2] Michael E. Eliot Hurst, *A Geography of Economic Behavior: An Introduction,* Belmont, California: Duxbury Press, 1972, p. 231.

[3] Ibid.




URBAN LAND-USE LOCATION SCHEME (AFTER HURST, p. 231)
Figure 1.

Commercial activities are potentially the highest bidders for sites and usually occupy the most accessible places within the city. But commercial land uses are also found in the industrial and residential zones. Similarly, residential uses may also be found in other zones. For example, a four-story apartment building may yield several times more rent than a one-story commercial operation on the same site and thus may out-bid competitors for the property.[4]

Bid-rent functions are a very important real world phenomenon encountered in explaining land use site selections. Industries seeking highly accessible sites upon which to build must compete against other bidders for those same sites. Consequently cost per unit acre, distance from CBD and proximity to transportation facilities were included as variables to be examined in this study.

## Uber den Standort der Industrien[5]

Alfred Weber was among the first economists to pose a general theory of industrial plant location. The optimal location for an industrial plant was seen to be a formation of three factors: transportation costs, labor costs, and agglomerative forces. Weber theorized that the optimal location would be found:

1. where total transportation costs per unit of output were at a minimum or,

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[4]Ronald Reed Boyce, *The Bases of Economic Geography: An Essay on the Spatial Characteristics of Man's Economic Activities* (Atlanta: Holt, Rinehart and Winston, Inc., 1974), p. 264.

[5]Alfred Weber, *Uber den Standort der Industrien* (Chicago: University of Chicago Press, 1928).

2. where transportation diseconomies were offset by savings through agglomeration factors or access to labor.

Of particular interest in this study are Weber's ideas concerning agglomerative factors and proximity to labor. In general, the ideas posited by Weber are of greater importance at the regional or sub-regional levels of industrial location than at the site level. Some of Weber's agglomerative factors, however, relate to industrial site characteristics and, thus, are considered in this analysis.

Weber's agglomeration factors are:

(1) The joint development of industries which promotes the attraction of auxiliary industries and increases the efficiency of large scale production and utilization of special technical equipment.

(2) The development and growth of specialized labor due to the greater opportunity for work in the area.

(3) The greater accessibility to raw material suppliers who can provide material regularly and on short notice.

(4) The reduction in overhead costs, such as gas, water, electricity, roads, and communications.[6]

The Location of Economic Behavior[7]

The American economist, Edgar Hoover initially attempted to improve Weber's explanation of industrial location by including the consideration

[6]Robert G. Turner, "General Theories of Plant Location: A Survey," *AIDC Journal*, VI (October 1971), pp. 25-26.

[7]Edgar M. Hoover, *The Location of Economic Behavior* (New York: McGraw-Hill, 1949).

of such variables as the size of market area and institutional forces in his theoretical analysis. Yet Hoover, although critical of Weber's analysis, ultimately proceeded along the same lines to present his location theory primarily in terms of costs. Hoover, however, did expand Weber's agglomerative forces to include the importance of banks, utilities, fire and police protection, climate, property tax, and lower interest rates.[8]

Hoover also developed some generalizations in the locational habits of light industry versus heavy industry. Because of the necessity of "handling of large quantities of goods either coming in from elsewhere or being shipped out, heavier types of manufacturing, warehousing, and wholesaling prefer locations in transhipment zones along rail or waterways." "Manufactures, wholesalers and warehouses of less bulky goods need not be located on railroads or waterfronts at all, since they can be served by truck." They locate more in response to "the attractions of labor supply, cheap land, and nearness to local suppliers or customers. As a rule, they are found interspersed with commercial and inferior residence uses."[9]

The site considerations of industries of the 1930's and 40's have changed in more recent times but several basic locational rules as expressed by Hoover and Weber remain intact. Accordingly, several

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[8] Turner, op. cit., p. 27.

[9] Hoover, op. cit., pp. 128-129.

variables such as neighborhood amenities, neighborhood compatibility, proximity to labor force, availability of utilities, types of adjacent land uses, and transportation accessibility have been included in this analysis.

Imperfect Competition and the Duopoly Debate

A number of location theorists believed pure competition was not a suitable theoretical structure for the study of plant locations, and sought to explain locations in terms of the competition between two firms attempting to capture the largest share of a market area.

Fetter[10] and Hotelling[11] were among the earliest to expound on duopoly location theory. They were followed by Lerner and Singer,[12] Smithies,[13] and Chamberlin[14] who expanded the original concept.

Devletoglou[15] recently commented on the economic irrationality of the approach and presented arguments against the theoretical base for

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[10] Frank A. Fetter, "The Economic Law of Market Areas," *Quarterly Journal of Economics*, XXXVIII (May 1924), pp. 520-529.

[11] Harold Hotelling, "Stability in Competition," *Economic Journal*, XXXIV (March 1929), pp. 41-57.

[12] A. P. Lerner and H. W. Singer, "Some Notes on Duopoly and Spatial Competition," *Journal of Political Economy*, XLV (April 1937), pp. 145-186.

[13] Arthur Smithies, "Optimal Location in Spatial Competition," *The Journal of Political Economy*, XLIX (June 1941), pp. 423-439.

[14] E. H. Chamberlin, *The Theory of Monopolistic Competition* (Cambridge: Harvard University Press, 1936), pp. 194-196.

[15] Nicos E. Devletoglou, "A Dissenting View of Duopoly and Spatial Competition," *Economica* (May 1965), pp. 140-160.

such location activities. Important contributions, however, are still to be noted. Duopoly theory suggests consideration should be given to the repelling or attracting properties of industries which depend upon local markets.[16]

## The Theories of David M. Smith[17] and Melvin L. Greenhut[18]

Smith's and Greenhut's contribution to the theory of industrial location incorporated the minimum costs approach of Weber with the maximum profit solutions of manufacturing location posited by August Lösch.[19] Smith calls this the maximin solution. The concept developed is illustrated in Fig. 2.[20] In (a), the costs of production are permitted to vary over space (distance) and revenue obtained (demand) is kept constant. This is essentially the Weber solution. The basic concept of Lösch's model is shown in (b), where revenue is permitted to vary over space and costs are held constant. Finally, in (c) the combined solution suggested by Smith is offered with maximum profit

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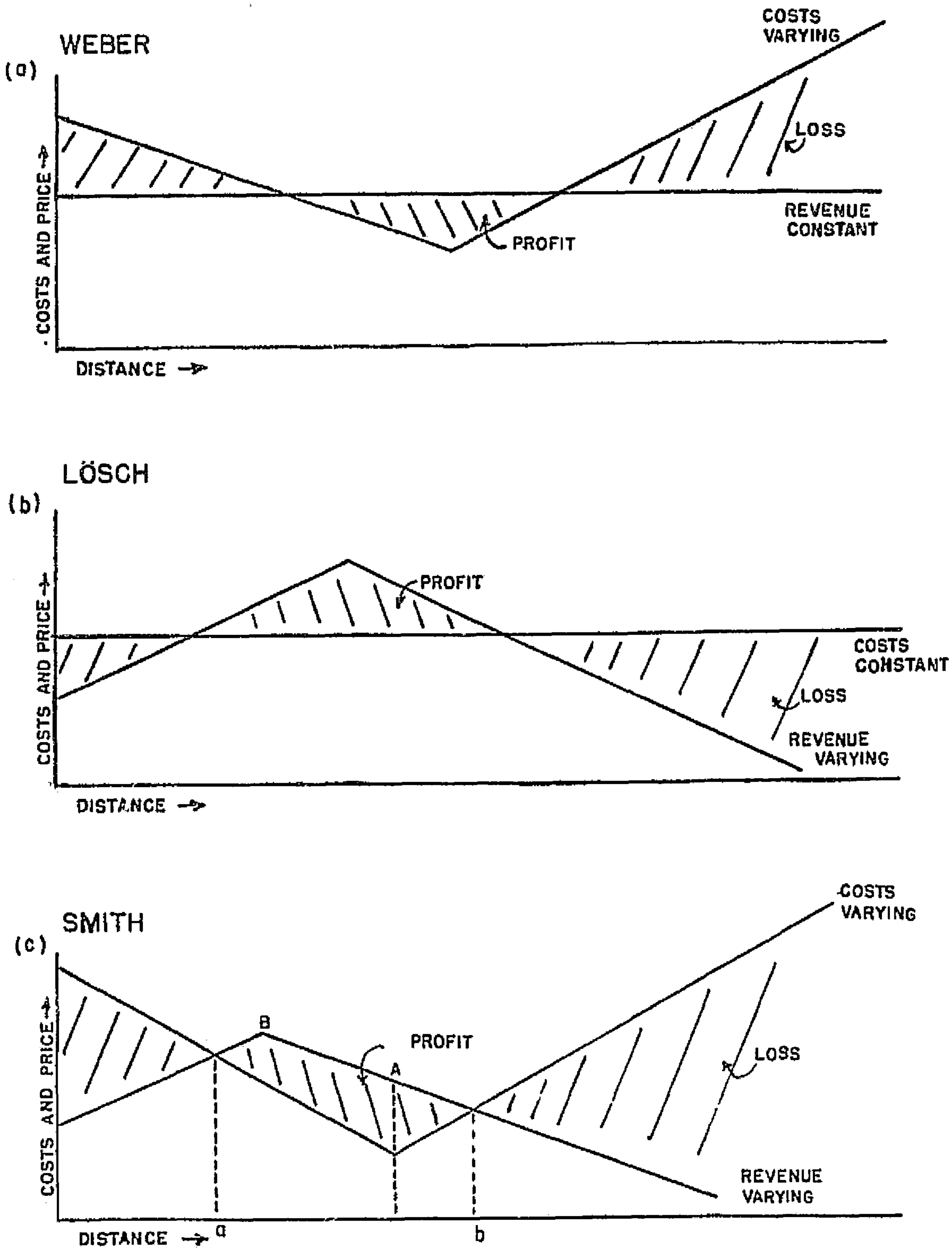
[16]Turner, op. cit., p. 31.

[17]David M. Smith, "A Theoretical Framework for Geographical Studies of Industrial Location," *Economic Geography* XLII (April 1966), pp. 95-113.

[18]Melvin L. Greenhut, *Plant Location in Theory and in Practice* (Chapel Hill: University of North Carolina Press, 1956).

[19]William H. Weglom and Wolfgang F. Stalper (Translators), *The Economics of Location,* by August Lösch (New York: John Wiley and Sons, 1957).

[20]Smith, op. cit., p. 96.




SMITH'S MODEL WITH COMPARISONS (AFTER SMITH, p. 96)
Figure 2.

occurring at A, where costs are lowest and profit is highest. Note that maximum revenue, however, is obtained at B.[21]

An interesting variation of Smith's model was the introduction of noneconomic factors, in particular, the concept of psychic income. This innovation permitted social, psychological, or other personal factors to be entered into the model, hence relaxing the traditional assumption of economic man. Such considerations according to Smith tend to divert the location of a plant from the ideal site to locations closer to the owner's home, a golf course, or perhaps a parochial school.[22]

Smith suggests that stochastic procedures may ultimately have to be used to simulate industrial location decisions as personal factors cannot be accounted for by rigorous mathematical reasoning.[23] This research assumes that personal considerations may be accounted for by noting neighborhood amenities near the potential site. The importance of housing quality, proximity to churches, hospitals, schools, or parks and personal services availability in the immediate vicinity of the site are examined in this study.

## Empirical Studies of Industrial Site Selection

The following empirical studies were significant resources in the development of a tentative list of site-selection variables for the

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[21] Ibid., pp. 96-97.

[22] Ibid., p. 108.

[23] David M. Smith, *Industrial Location: An Economic Geographical Analysis* (New York: John Wiley and Sons, Inc., 1971), pp. 269-273.

industrial land use analysis. Two types of studies are presented: those studies directed primarily toward the industrial developer who seeks new industry for a community; and those studies which attempt to analyze industrial location considerations by way of a large sample of new industries and to categorize the locational considerations by industry types. Only one study is directed toward the development of a site-selection algorithm for a land use model.

The Studies of Allen Pred[24] and Richard Lonsdale[25]

Allen Pred has compiled a study of the history and present status of industrial location decisions within a metropolitan region. The discussion posed many interesting hypotheses for empirical analysis but this research interest is directed primarily to the site characteristics discussed by Pred. It should be noted that Pred's analysis focused upon a single metropolitan area whereas this study encompasses a region with a hierarchy of urban places.

In discussing location patterns, Pred identifies seven types:

1. Ubiquitous industries concentrated near the CBD - The market area of these industries is generally coincident with that of the metropolis or city. Food processing industries, specifically bakery goods, package foods, and fresh milk products, are some examples of these types of industries.

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[24] Allen R. Pred, "The Intrametropolitan Location of American Manufacturing," *Annals of the Association of American Geographers*, LIV (June 1964), pp. 165-180.

[25] Richard E. Lonsdale, "Rural Labor as an Attraction for Industry," *AIDC Journal*, IV (October 1969), pp. 11-17.

2. Centrally located "communication-economy" industries - Job-printing industries, newspaper printing, and advertising printing would be representative industries of this category.

3. Local market industries with local raw material sources -These industries show a high degree of randomness in their locational pattern but with some tendency toward CBD locations. Samples would be ice plants, concrete brick and block industries or industries whose raw materials are by-products of other large-scale industries such as the pulp and paper products industry.

4. Non-local market industries with high value products - Typically these industries provide a high value per unit weight product and are insensitive to transport considerations within the local region. The pattern is "at least superficially irrational." Computer and related industries and chemical industries are typical examples.

5. Noncentrally located "communication-economy" industries - The subset of industries includes those which are not necessarily pulled to any functional area of the city but rather tend to cluster together in any suitable area primarily because of the necessity to "keep abreast of the latest innovations or forthcoming contracts." Electronic, military equipment, and space age industries such as found in Huntsville, Alabama, or Houston, Texas, are examples.

6. Non-local market industries on the waterfront - Industries where primary raw materials are imported by water or whose finished products are often moved by water comprise this group. Petroleum refining, coffee roasting, and sugar refining are prominent among these types of industries.

7. Industries oriented toward national markets - These industries have extensive market areas and are influenced by high transportation costs on a bulky finished product. A large percentage of these industries have a tendency to locate on the side of the metropolis facing the most important market region. Pred identifies the Newark Lowland refining industry and the Detroit automobile industry as examples.[26]

Richard Lonsdale in a study of the locational habits of rural industry notes that those industries affected by transportation costs tend to locate in urban areas while those highly affected by labor costs gravitate to rural areas. In addition, Lonsdale notes rural firms tend to space themselves out in order to assure a labor supply.

Industries with tendencies toward rural locations are apparel, food products, textile, lumber and wood products, paper products, chemical, and electrical machinery - especially routine assembly. Low profit margins, keen competition, and high percentage[27] of production workers are some basic characteristics of these industries.

The patterns of industrial location detailed by Pred and Lonsdale are primarily identified with a spatial level slightly higher than the site-specific level which is the focus of this study. In relation to the study of the site-selection processes, variations in pattern are significant. It is obvious that for each industry type the weighting of the site factors will vary. This is not a primary objective of this

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[26]Pred, op. cit., pp. 175-178.

[27]Lonsdale, op. cit.

study; however, it was anticipated that after analyzing the general site-selection process, additional research would permit the matching of various types of manufacturing to specific types of sites.

## Historical Studies of Industrial Location Factors[28]

Numerous empirical studies exist of the factors associated with actual industrial location events. Although many of these studies were undertaken by academicians, the normal viewpoint assumed is that of the industrial developer seeking to attract new industry or expand existing industry within the community.

Characteristically, investigations of this type are not concerned with a specified theoretical framework for approaching the problem

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[28] Discussion within this section is based mostly upon a review of the following articles: J. S. Bullington, "Utilization of State-Wide Site Evaluation Committee to Aide in the Location or Relocation of Plant Facilities," *AIDC Journal*, IV (October 1969), pp. 27-42; James E. Chapman and William H. Wells, "Factors in Industrial Location in Atlanta, 1946-1955," *Atlanta Economic Review*, IX (September 1959), pp. 3-8; Ronald E. Carrier and William R. Schriver, "Location Theory: An Empirical Model and Selected Findings," *Land Economics*, XLIC (November 1968), pp. 450-460, and a more complete explanation of the study: Ronald E. Carrier and William R. Schriver, *Plant Location Analysis: An Investigation of Plant Location in Tennessee* (Memphis: Memphis State University, 1969); Melvin L. Greenhut and Marshall R. Colberg, *Factors in the Location of Florida Industry* (Tallahassee: The Florida State University, 1962); T. E. McMillan, "Why Manufacturers Change Plant Location versus Determinants of Plant Location," *Land Economics*, XLI (August 1965), pp. 239-243; N. J. Stefaniak, *Industrial Location within the Urban Area: A Case Study of Locational Characteristics of 950 Manufacturing Plants in Milwaukee County* (Milwaukee: Wisconsin Commerce Reports, 1962); Charles M. Tiebout, "Location Theory, Empirical Evidence and Economic Evolution," *Regional Science Association, Papers*, III (1957), pp. 74-86; U. S. Department of Commerce, *Industrial Location Determinants*, 1971-1975 (Washington, D. C.: U. S. Department of Commerce, Economic Development Administration, February 1973); and D. C. Williams and Donnie L. Daniel, "Industrial Sites for Small Communities," *AIDC Journal*, VI (April 1971), pp. 33-39.

but rather with the reasons for the location decision as perceived by persons acquainted with the location event. None of these studies was concerned with the construction of an algorithm to simulate the process of industrial land use development.

Greenhut and Colberg[29] analyzed factors influencing the decisions of 400 manufacturers locating in the State of Florida between 1956 and 1957. Location considerations were divided into three groups: demand (market) considerations, cost (assembly) considerations, and personal (psychic) considerations. Access to markets and potential markets (Table 2) rated the highest among the location factors with the remaining factors surprisingly low. The study, however, was slanted toward measuring regional and subregional factors and thus was of limited value to this study.

The extensive study undertaken by Carrier and Schriver[30] of plant locations in Tennessee between 1955 and 1965 was conducted within the framework of existing location theory and, in part, did focus upon site-location factors. Many of the variables included in this analysis are based upon the conclusions reached in this study.

Carrier and Schriver identified six classes of location factors believed capable of affecting plant locations: (1) personal factors, (2) procurement-cost factors, (3) processing-cost factors, (4) distribution-cost factors, (5) location demand factors (including locational interdependency considerations), and (6) certainty factors.[31] (This

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[29]Greenhut and Colberg, op. cit.

[30]Carrier and Schriver, op. cit.

[31]Carrier and Schriver, op. cit., p. 451.

| Location Factors | Percentage of 400 Plant Listing as Primary Factor |
|---|---|
| Access to markets | 51.9 |
| Anticipation of market growth | 12.8 |
| Good labor relations | 1.7 |
| Lower wages | 2.6 |
| Ease of attracting out-of-state personnel, including research | 4.7 |
| Low freight cost on obtaining raw materials and components | 7.7 |
| Low cost on freight on shipping final product | 10.7 |
| Climate as it affects operations | 1.8 |
| Community facilities (education, police, medical, etc.) | 2.9 |
| All other factors | 3.2 |

FACTORS MOST INFLUENTIAL IN THE LOCATION DECISIONS OF FLORIDA INDUSTRIES, 1956-1957

TABLE 1

class was identified after the interviews.) Certainty factors were defined as the confidence that the "prevailing and forecasted data used to identify the site offering maximum profits would persist into the future."[32]

Persons involved in the selection of sites for 307 manufacturing plants were interviewed. Each respondent was asked to select six factors from those listed in Table 2 and to distribute 100 points among these six in order to indicate the relative importance each factor contributed to the total plant location decision.

Of the 36 factors listed in Table 2, low cost and availability of labor was mentioned most frequently as the primary factor affecting the location decision (Table 3). Personal considerations without economic advantages received the highest average number of points, followed by low cost and availability of labor (Table 4).

On the basis of the interviews the authors grouped industries according to the six factors previously listed:

(1) Personal factors - Miscellaneous manufacturing, furniture and fixtures, and food and kindred products were highly sensitive to personal factors with most of those firms being "home-grown."

(2) Procurement-cost factors - Industries which need large volumes of low-unit-value or perishable raw materials were characteristically affected by this group of factors. Food and kindred products, stone, clay and glass products, and lumber and wood products industries indicated greater sensitivity to these factors.

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[32]Ibid.

1. Personal Factors:

    Personal with economic advantages
    Personal without economic advantages

2. Procurement-Cost Factors:

    Better service from seller of raw materials and components
    Low cost on raw materials or components
    Availability of low cost raw materials

3. Processing-Cost Factors:

    Low cost and availability of labor
    Low cost of fuel
    Low cost of electric power
    Low cost of financing project through Area Redevelopment Administration
    Climate
    Favorable labor-management relations
    Low cost of satisfactory type of water
    Adequate waste disposal
    Low cost of building and land
    Low cost of financing plant through revenue or general obligation bonds
    Favorable community and state tax structure
    Community concessions
    Available existing plant
    Available existing building
    Particular characteristics of building site

4. Distribution-Cost Factors:

    Low freight cost, finished product

5. Location-Demand Factors:

    Greater demand in the area
    Greater demand potential in the area

6. Certainty Factors:

    Nearness to metropolitan city
    Community facilities
    Community planning and zoning laws
    Cultural qualities of the town
    Community leaders' cooperation
    Size of city
    Data provided by Chamber of Commerce, community, etc.
    Information provided by local manufacturers
    Recreation, a good place to live, etc.
    Nearness to corporate headquarters
    Local supporting services
    State administration neutral in labor-management relations
    Progress in racial adjustment
    Data provided by the state industrial development agency

LIST OF POSSIBLE FACTORS INFLUENCING INDUSTRY LOCATION AS UTILIZED IN THE CARRIER AND SCHRIVER SURVEY[33]

TABLE 2

[33] *Ibid.*, p. 453.

| Factor | Percent of Firms | Rank |
|---|---|---|
| Low cost and availability of labor | 65.6 | 1 |
| Low cost of electric power | 36.0 | 2 |
| Favorable labor management relations | 35.7 | 3 |
| Community leaders' cooperation | 32.2 | 4 |
| Low cost of building and land | 19.8 | 5 |
| Low freight cost, finished product | 17.9 | 6 |
| Available existing plant | 17.5 | 7 |
| Favorable community and state tax structure | 17.2 | 8 |
| Low cost of financing plant through revenue or general obligation bonds | 16.9 | 9 |
| Available existing building | 16.6 | 10 |

TEN FACTORS MOST FREQUENTLY MENTIONED BY TENNESSEE
FIRMS AS AFFECTING THE LOCATION DECISION

TABLE 3

| Factor | Percent of Firms | Rank |
|---|---|---|
| Personal without economic advantages | 49.2 | 1 |
| Low cost and availability of labor | 38.0 | 2 |
| Available existing plant | 35.9 | 3 |
| Personal with economic advantages | 32.9 | 4 |
| Availability of low cost raw materials | 31.9 | 5 |
| Greater demand in area | 30.2 | 6 |
| Greater demand potential in area | 29.8 | 7 |
| Low cost of financing project through Area Redevelopment Administration | 29.6 | 8 |
| Available existing building | 27.6 | 9 |
| Nearness to corporate headquarters | 26.0 | 10 |

TEN LOCATION FACTORS WITH HIGHEST MEAN NUMBER POINTS ASSIGNED BY TENNESSEE FIRMS INTERVIEWED

TABLE 4

(3) Processing-Cost Factors - These factors are associated with in-plant costs in assembling or processing the finished product, e.g., labor, energy, external services, capital, land costs, etc. Electrical machinery, apparel and related products, and textile mill products industries were affected by these factors.

(4) Distribution-Cost Factors - These factors reflect the costs incurred in shipping the finished products to the buyer. Among the most sensitive to these factors were food and kindred products, miscellaneous manufacturing, and paper and allied products industries.

(5) Location-Demand Factors - Industries affected by these factors are highly sensitive to market-demand in terms of proximity. Included in this category are paper and allied products, printing and publishing, and primary metal industries.

(6) Certainty Factors - The validity of existing and forecasted data is considered to be highly important by industries affected by these considerations. In other words, these industries want to know the future stability of costs in production and the probable continuance of existing markets. Printing and publishing, leather and leather products, and transportation industries were highly sensitive to these factors.

It is obvious that the scope of the Carrier and Schriver study is much broader than the objectives of this study. Its utility, therefore, is limited. The factors considered by Carrier and Schriver span several spatial levels of locational decisions. The result is that factors which may be very important at the site-selection level are weighted low in comparison to the total list of factors. Also, the disproportionate

number of factors offered for consideration under the six categories tends to skew the weightings. Finally, the lack of a very large sample in specific SIC categories tends to decrease the validity of the results of the weightings and, therefore, the conclusions reached regarding the typical locational patterns of specific industries.

Bullington[34] offers a scheme to locate potential industrial sites on a state-wide basis by suggesting the scoring of location factors on an ordinal scale and aggregating them into an index to determine the site potential for specific industries. Bullington assumed that local and state governments could match the qualities of the industrial sites available in the community to specific industries to assist in the search for new industry. The factors which Bullington suggests are listed in Table 5.

The U. S. Department of Commerce recently published the partially aggregated results of an extensive 5-digit industrial location survey conducted by mail throughout the U.S.[35] The purpose of the survey was "to assist the nation's underdeveloped and declining areas in the development of their economic resources and potentials."[36] Only manufacturing industries demonstrating "reasonable" growth between 1958 and 1967 were selected for inclusion in the survey. Survey forms were mailed to a total of 2,950 companies in 254 different SIC categories. One form,

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[34] J. S. Bullington, "Utilization of a State-Wide Site Evaluation Committee to Aide in the Location or Relocation of Plant Facilities," *AIDC Journal*, IV (October 1969), pp. 27-42.

[35] U.S. Department of Commerce, *Industrial Location Determinants, 1971-1975* (Washington, D.C.: U.S. Department of Commerce, Economic Development Administration, February 1973).

[36] Ibid., p. 1.

Site Characteristics

a. Size of Parcel
b. Shape of Parcel
c. Topography
d. Drainage
e. Flood Record
f. Condition and Appearance
g. Underground Water
h. Soil Bearing Capacity
d. City Water
e. City Sewer
f. Limitations of Site

Acceptability

(This referred to the potential friction or good-will prompted by the location of industry)

Accessibility

a. Highway
b. Secondary Roads
c. Rail

Community Factors

a. Commercial Air Service
b. Water Transport
c. Location in State
d. Mileage Rate
e. Airport Facilities
f. Comprehensive Planning and Zoning
g. Retail Accommodations
h. College
i. Community Appearance
   a. retail
   b. residential
j. Highways
k. Presentation of Facts by Community
l. Sanitary Sewer and Water Treatment and Facilities

LOCATION FACTORS SUGGESTED BY BULLINGTON

TABLE 5

*Survey of Industrial Location Determinants*, was to be completed by all companies to identify the locational and operating characteristics of existing plants. The attributes measured or assessed in the survey are only slightly coincident with those sought in this analysis and span several spatial levels of the locational decision process. Only a summary of the results has been published to date and its usefulness for this study is limited because of the highly disaggregated form of the report. Hopefully, these data will eventually be digitized and be available for future analysis purposes. Nevertheless, some of the variables utilized in the survey were included in this analysis.

## Residential Location and Land Use Modeling Studies

Site-selection algorithms are certainly not novel to land use modeling methodologies. Numerous modeling efforts have utilized various allocation systems to distribute projected change in land use. Most of these, however, were designed to operate at smaller scales of allocation (usually at the census tract or county level) simply because data (e.g., census materials) to calibrate the models are more readily available at that level. The following studies noted have approached the allocation problem similar to this study and provide input to conceptualization and determination of variables to be utilized in studying industrial and residential land use change.

Among the first land use models to utilize a site-selection algorithm to distribute projected land use change was developed at the University

of North Carolina by Donnelly, Chapin, and Weiss.[37] The primary purpose of the model was to simulate the growth and spatial spread of residential land use over time. Residential growth was considered to occur as the result of "priming actions" such as the location of new industry, expressway completion, or the installation of a new sewer or water line. The "priming actions" were considered to be given. Beginning from land use patterns existing in the past, the model would simulate by incremental time periods, growth of residential land use to the present. Residential growth was allocated to 2.5-acre land development cells on the basis of probability values reflecting each cell's attractiveness for residential development. The attractiveness values were permitted to vary not only as new residential development was added, but also as the "priming actions" were known to have occurred. In effect, the model was simply an attempt to replicate what happened in the past. Extension of residential development into the future was based on the assumption that development processes would remain constant.

Historical data compiled for the period between 1948 and 1960 were utilized to calculate attractiveness probabilities and to schedule the "priming" events. Changes were recorded by means of 1000-foot cells composed of nine 2.5-acre land development units.

Details of the computer simulation routine follow:

1. All land within the city unsuitable for development is eliminated from consideration at the beginning and the supply

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[37]Thomas G. Donnelly, F. Stuart Chapin, and Shirley F. Weiss, *A Probabilistic Model for Residential Growth* (Chapel Hill: University of North Carolina, Institute for Research in Social Science, 1964).

of land remaining is identified as available for residential use. Available land is coded as either vacant, subdivided, or raw land.

2. For each 1000 foot cell, a measure of relative value is established; that is, land value in terms of a cell's attractiveness for residential development.
3. The effect that "priming" (expansion of municipal services, commercial services, and industrial development) decisions will have on modifying the value of the property is then calculated for each cell. These are exogenously given and the time and amount are known from historical data collected between 1948 and 1960.
4. Land parcels are then "reassessed" to obtain a new attractiveness score based upon the "priming actions" that will occur in the time interval considered.
5. Density constraints (numbers of units per acre/year) are then introduced.
6. Finally, known growth in residential households between 1948 and 1960 is allocated by 2-year time periods on a probability basis.[38]

The model structure developed by Donnelly et al., was basic to the original conceptualization for this study. Historical data were employed to calculate the allocation probabilities but little understanding of the process (cause-effect) was required. The study illustrated problems associated with a stochastic approach toward land use modeling but also demonstrated how the model might be used in a heuristic manner

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[38] Ibid, p. 11.

to understand residential development. The concepts generated by this study have been basic to many subsequent modeling efforts and provided insight for this study as well. A Ph.D. dissertation by Edward Kaiser is one example of an extension of the University of North Carolina study.[39]

Kaiser's work focuses specifically upon the residential developer's locational behavior. The study examined the role of the developer in an urban residential extension and was limited to the explaining and prediction of "where" residential extension might occur rather than how much, when, or at what rate. Site characteristics were grouped into three categories: physical, locational, and institutional (Table 6).

In his empirical analysis of subdivision location, Kaiser utilized both univariate (Goodman-Kruskal analysis) and multivariate (MANOVA) statistical analysis to identify conceptual variables to be utilized in modeling residential subdivision location.[40] From his analysis, Kaiser concluded that site characteristics, type of developer, and intended market of subdivision appear to be the most promising measures in residential development potential. Of the site characteristics those variables in the locational category had the strongest association with subdivision development while physical characteristics were generally found to be weak in association.

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[39]Edward J. Kaiser, "Toward A Model of Residential Developer Locational Behavior," Ph.D. Dissertation, University of North Carolina, 1966; and Edward J Kaiser and Shirley F. Weiss, *Decision Models of the Residential Development Process: A Review of Recent Research* (Blacksburg, Va., Virginia Polytechnic Institute, Southeastern Regional Science Association, 1969).

[40]Kaiser, pp. 185-186.

I. Physical Characteristics

a. Size of the tract of raw land
b. Topography
c. Soil conditions
d. Ground cover

II. Locational Characteristics

a. Social location
b. Proximity to transportation
c. Accessibility to schools
d. Accessibility to shopping
e. Accessibility to employment
f. Proximity to existing development
g. Visual quality of the approach route to site
h. Proximity to incompatible uses

III. Institutional Characteristics

a. Governmentally imposed boundaries for:

1) water and sewer service
2) zoning regulation
3) subdivision regulation
4) school districts

b. Ownership patterns:

1) size of parcels under separate ownership
2) whether or not parcel is on the market
3) terms of availability of parcel

c. Marketability rating by financial institutions

SITE CHARACTERISTICS UTILIZED IN KAISER'S STUDY OF RESIDENTIAL DEVELOPMENT

TABLE 6

Kaiser's study provides a base for further analysis of residential land use development and suggestions as to promising methodology. He did not utilize factor analysis, but he suggested that such procedures should be utilized in future studies.

The Pittsburgh industrial location model, INIMP[41] (Industrial Impact Model), is similar to the model design suggested in this study; the major difference being that growth is distributed to census tracts and consequently the variables are generally more aggregated than those considered in this study.

Four variables (attributes of census tracts) and one constraint were identified as sufficiently discriminatory to determine site locations. These are: weighted mean unit-assessed value of land; weighted mean unit-assessed value of buildings; weighted mean structural density, and amount of industrial clustering. These measures were determined by census tract. The constraint can either be imposed artifically as in the case of zoning controls or nonexistence of services; or directly imposed by the model operator. On the basis of the aggregated scores of the indexes, the model distributes a portion of projected city-wide employment change among existing facilities and, upon reaching certain critical values of saturation, switches to a separate routine to distribute new facilities to census tracts having the highest suitability values for the remainder of the projected industrial employment growth. The algorithm utilized may be classified as a Lowry type of model.

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[41]Steven H. Putman, "Intraurban Industrial Location Model Design and Implementations," *Regional Science Association, Papers*, IXX (1966), pp. 199-214.

The Harvard study[42] utilized a one-square kilometer cell size and a UTM grid system. The study area was located in the southwest portion of the Boston Metropolitan region and encompassed 1,296 square kilometers (520 square miles). Simulation of land use change was based upon a set of simple algorithms and assumed no changes in previous land development processes. Four land use allocation models were prepared by student teams: an industrial model, a residential model, a recreation and open space model, and a commercial center model. Each allocation algorithm was designed to operate within its own set of objectives, independent of the other algorithms. In addition to the above models, four evaluation models were developed to assess political, physical, visual clarity, and pollution impacts.

Each land use allocation model was based upon linear regression analysis. For example, the attractiveness for each cell for various types of housing was determined by regressing other variables against land value. Maps of the regression scores were then utilized to allocate new housing with the highest valued sites used first. Data sets (see Table 7) were collected for each cell in the study area, utilizing existing USGS topographic maps and aerial photography as source materials.

One of the more promising regional modeling simulation studies is located at the University of British Columbia.[43] The project called

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[42] Carl Steintz and Peter Rogers, *A System Analysis Model of Urbanization and Change: An Experiment in Interdisciplinary Education* (Cambridge: M.I.T. Press, 1971).

[43] M. A. Goldberg, *Quantitative Approaches to Land Management* (Vancouver, B.C.: University of British Columbia, The Resource Science Center, 1970); and David Baxter, Michael Goldberg, David Lach, and Gregory Mason, *Toward a Regional Housing Model* (Vancouver, B.C., University of British Columbia, July 1972).

| | |
|---|---|
| Landform | Institutions and services, major type |
| Depth to bedrock | Distance from elementary schools (within towns) |
| Soil texture | Sewer facilities and potential capacity |
| Drainage, percent well drained | Garbage dumps and incinerators (data for MAPC area only) |
| Topographic elevation in feet | Air and rail transport, major type |
| Topography, slope | Travel time by public transit to downtown Boston |
| Topography, visual closure, type of largest percent of the cell | Road transport, 1965, major road type |
| Topography, visual closure, measure of a cell by its least absorptive part | Road transport, 1965, average daily car volume |
| Topography, visual closure, measure of a cell by its most absorptive part | Road transport, 1968, major road type (including proposed Route 495) |
| Water, percent of area | Access to limited access highways |
| Water, major type | Access to limited access highway interchanges |
| Water quality | Access to Route 128 |
| Water, navigation, by largest craft | Access to Interchange of Route 495 and Route 95 |
| Water supply potential | Access to Providence, R.I. |
| Forest, percent of area | Access to Framingham, Mass. |
| Vegetation density | Environmental nuisances, major type |
| Good agriculture, percent of area | Environmental nuisances, summary values |
| Poor agriculture, percent of area | Visual texture and landscape variation |
| Recreation, percent of area | Degree of visual complexity |
| Recreation, major type | Visual character, predominant type at most public area |
| Recreation, access | Visual access (summary value) |
| Residential, percent of area | Degree of visual effect (like-dislike) |
| Residential, predominant type | Land cost (recoded) |
| Residential density | Population per square mile by town |
| Residential cost and quality | |
| Residential, age of development | |
| Commercial, number of establishments | |
| Heavy industry, number of establishments | |
| Light industry, number of establishments | |
| Institutions and services, percent of area | |

VARIABLES UTILIZED IN THE HARVARD STUDY

TABLE 7

IIPS (Inter-Institutional Policy Simulator) has focused upon development of four interactive submodels: population, land use, employment, and transportation. The land use model is actually composed of several submodels with most of the emphasis upon the residential housing submodel. The housing submodel is composed of a macro-level algorithm (which estimates regional demands, regional supplies, and regional market adjustments in housing), and a micro-level algorithm (which approximates the local character of housing markets). The micro-level allocation is accomplished via supply-demand forecasting for 82 traffic zones. These traffic zones are assumed to be homogeneous aggregations of census tracts.

Aggregate demand for housing is allocated to subareas (traffic zones) on the basis of accessibility, topographic slope, current housing stock, average family size, and income and age characteristics of households. Housing supply for each subarea is calculated on the basis of actual and allowable densities, available land, accessibility, and excess supply by value class and structure type.

Although the spatial level is specified as micro, the Vancouver model actually operates at a regional scale when compared to this approach; however, the results were considered in developing the methodology for this study.

## Summary

The purpose of this chapter has been to review previous research relevant to understanding metropolitan land use conversion processes and to review those studies which have focused upon identifying land

parcels which have a strong probability of being converted to various land uses. Site characteristics and land use conversion processes which appear to affect land development decisions have been identified and the relative importance of each noted. This analysis of industrial land use and residential land use development utilized this information as a starting point for further research. The next section discusses the procedures used in this analysis.

# III. DESCRIPTION OF THE STUDY AREA AND PROCEDURES UTILIZED IN THE INDUSTRIAL LOCATION ANALYSIS

## The Study Region

The study region encompasses 16 counties surrounding and including Knoxville, Tennessee (Fig. 3) and represents an administrative entity called the East Tennessee Development District (ETDD). The region spans 6,500 square miles and contains a population of approximately 750,000 people. Its selection for this study was based upon the availability of data in the Oak Ridge National Laboratory (ORNL) Data Base.[1] ORNL selected the region on the basis of "the diversity of the region, the availability of data, the presence of cooperative and interested user groups, close proximity, (sic) etc."[2]

The ETDD region is centered in the southern portion of the Ridge and Valley Province (the "Great Valley"), bordered to the northwest by the Cumberland Plateau and Mountains, and to the southeast by the Great Smoky Mountain complex (Fig. 4). Both the Smokies and the Cumberlands are characterized by steep slopes and forest cover, with the Cumberlands distinguished by strip mining scars.

The area is drained by the Tennessee River system, the natural flow of which has been vastly altered by the Tennessee Valley Authority

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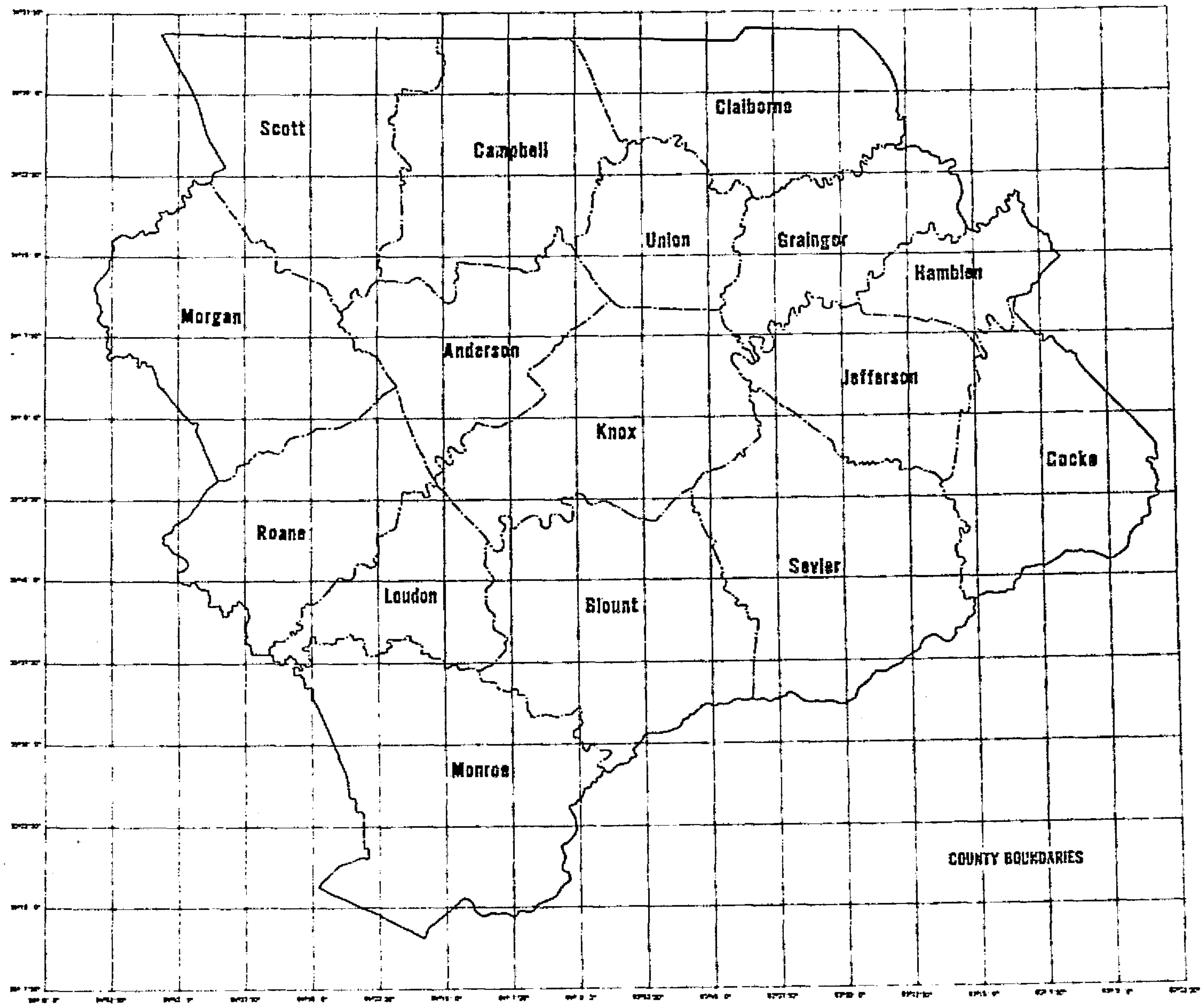
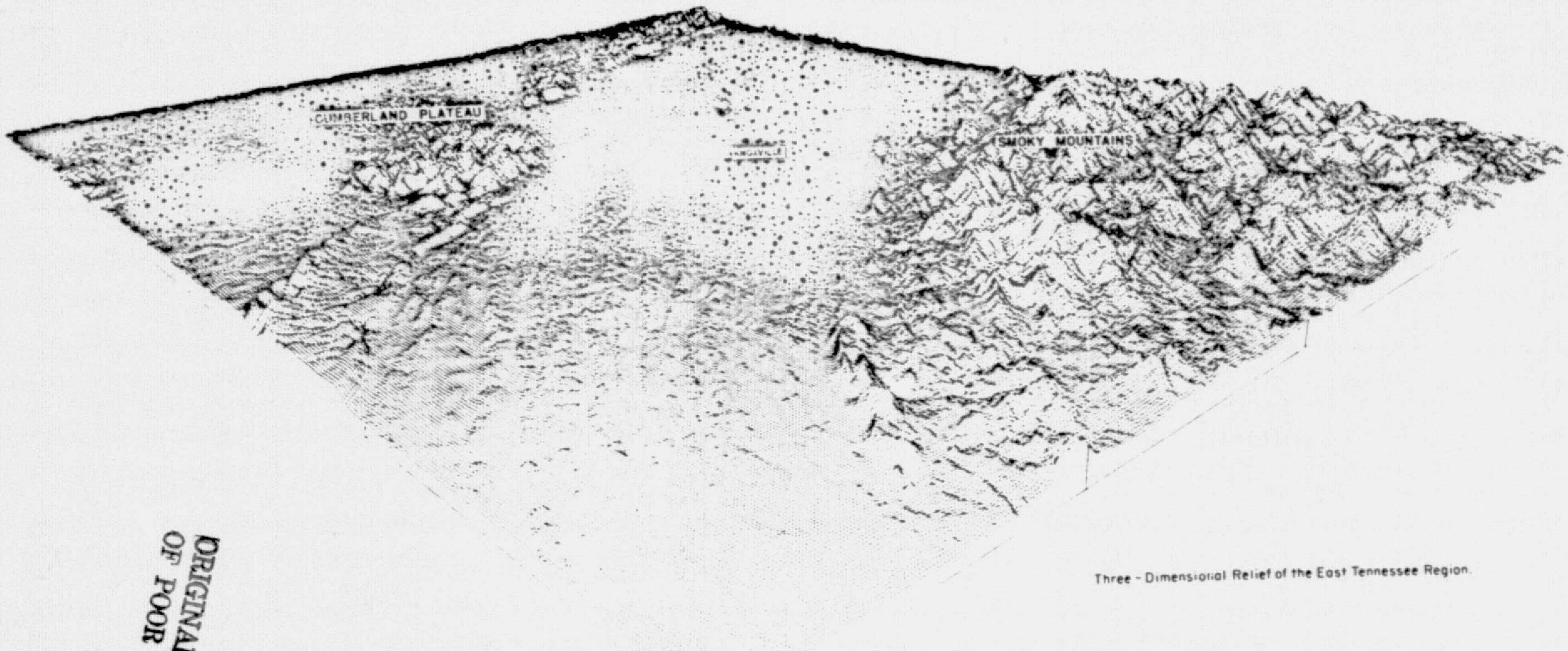
[1]Richard C. Durfee, *ORRMIS: Oak Ridge Regional Modeling Information System*, ORNL/NSF/EP-73, Oak Ridge National Laboratory, Oak Ridge, Tenn., September 1974.

[2]ORNL-NSF Environmental Program, *Regional Environmental Systems Analysis* (A Research Proposal Submitted to the National Science Foundation, February 1972), p. 3.




EAST TENNESSEE DEVELOPMENT DISTRICT
Figure 3.




Three - Dimensional Relief of the East Tennessee Region.



PHYSIOGRAPHY

Figure 4.

(TVA). By harnessing the power of the river system to produce low cost electrical power and developing a navigable channel to Knoxville, TVA has become the major development agency within the study region. As a result much of the land use development in the region has been structured by TVA activities.

The largest urban center in the region is Knoxville which serves as the major economic and transportation focus for the region. Surrounding Knoxville are Oak Ridge, Maryville-Alcoa, and more distant Morristown, each with 20,000 to 35,000 population. These cities perform subregional functions. Remaining urban centers are small in population and are mostly located in the valley between the plateau and the Blue Ridge (Fig. 5).

## Industry within the Region

This industrial analysis concentrated upon secondary manufacturing (SIC 20 through 39) and excluded extraction industry (SIC 10 through 19).[3] Location determinants of extraction (or primary) industry are dictated more by the distribution of raw materials and consequently the locational criteria of these industries will be different from secondary industries. For this reason primary industry is not considered in this study.

Categorically one could state that most of the industry within the region is concentrated in the Knoxville area. Of the 1002 industries in the region, approximately 46 percent are located in the immediate vicinity

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[3]Industries are referred to by their Standard Industrial Code (SIC) number throughout this study.

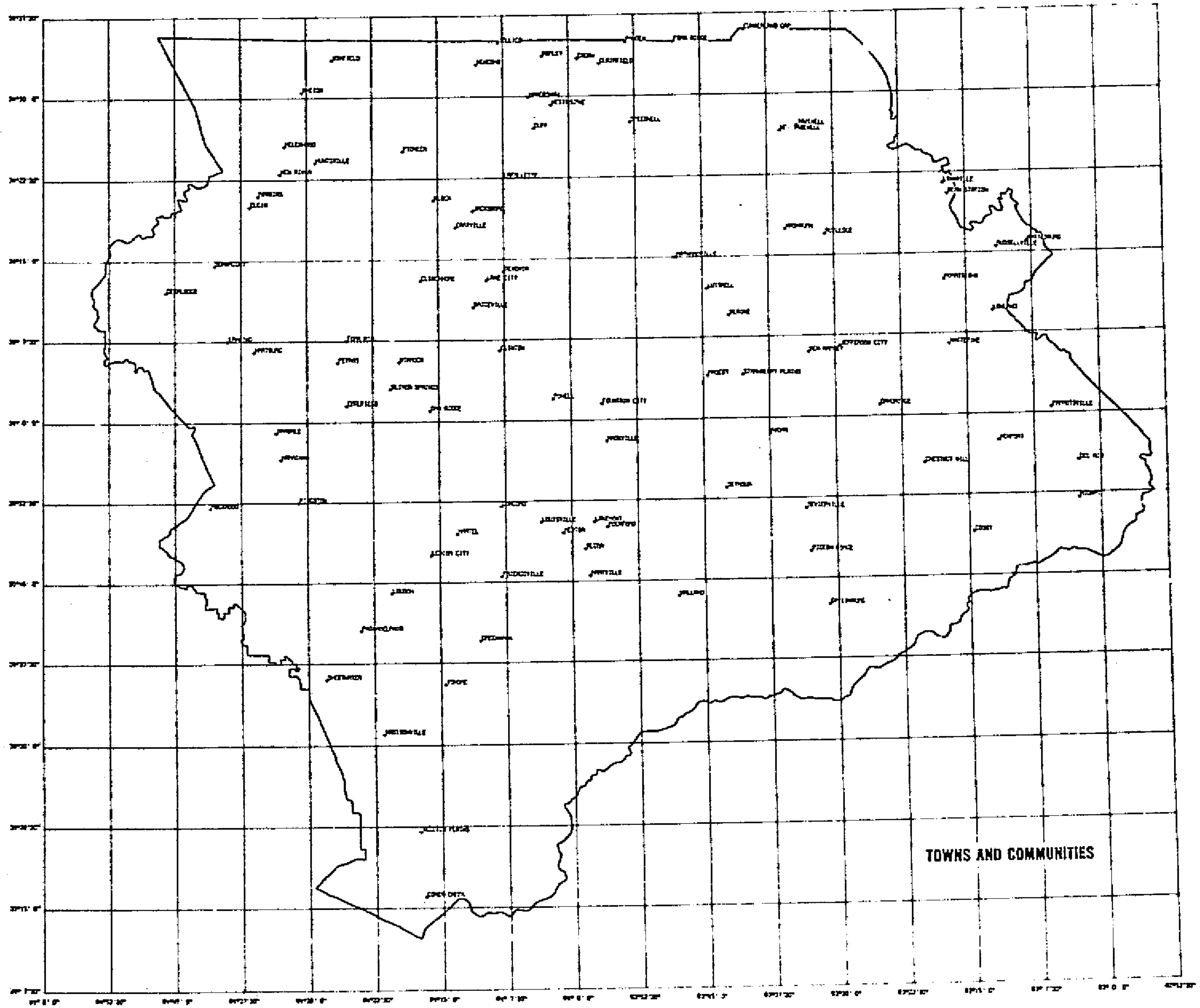



Figure 5.

of Knoxville. Knoxville also has the greatest diversity of industry, whereas industry in other communities is characterized by specific categories. (An example is the concentration of furniture industry in Morristown.)

Figures 6 through 13 provide a visual overview of the dynamics of industrial development in the region since 1943.[4] Since 1953 a 48 percent turnover in industry has occurred. Of the 1002 industries within the region in 1973, 488 have located in the 16-county region since 1953.

## Tentative List of Industrial Location Variables

Many of the studies reviewed in the previous section explain the problem of industrial location in terms of three components: demand, cost, and personal factors. Carrier and Schriver subdivided the process further into six components: personal factors, procurement-cost factors, processing-cost factors, distribution-cost factors, location-demand factors, and certainty factors. Only processing costs, procurement costs, distributing costs, personal costs, and certainty factors have any direct relationship to site location considerations. Certainty factors may be considered a variation of location-demand costs. At the site level, procurement costs and distribution costs are sensitive to one variable, accessibility. Considerations of freight rates, transport modes, proximity to raw materials, supplies, etc., are more related to locational considerations at the subregional level.

[4] C. R. Meyers, Jr., O. L. Ervin, D. L. Wilson, and P. A. Lesslie, *Spatial Distributions and Employment Trends of Manufacturing Industries in East Tennessee (1943-73)*, ORNL/NSF/EP-38, Oak Ridge National Laboratory, Oak Ridge, Tenn., March 1974.

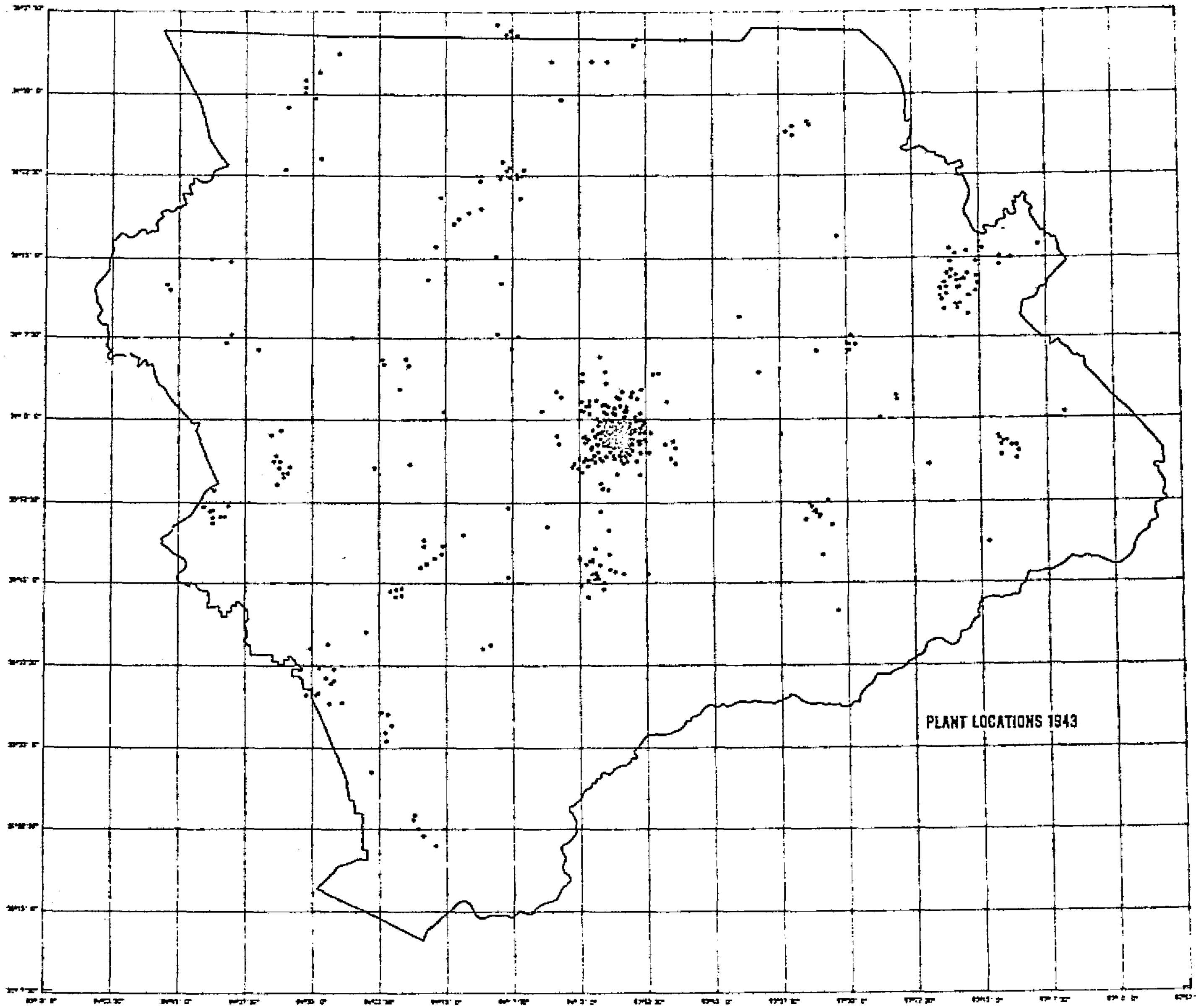



Figure 6.

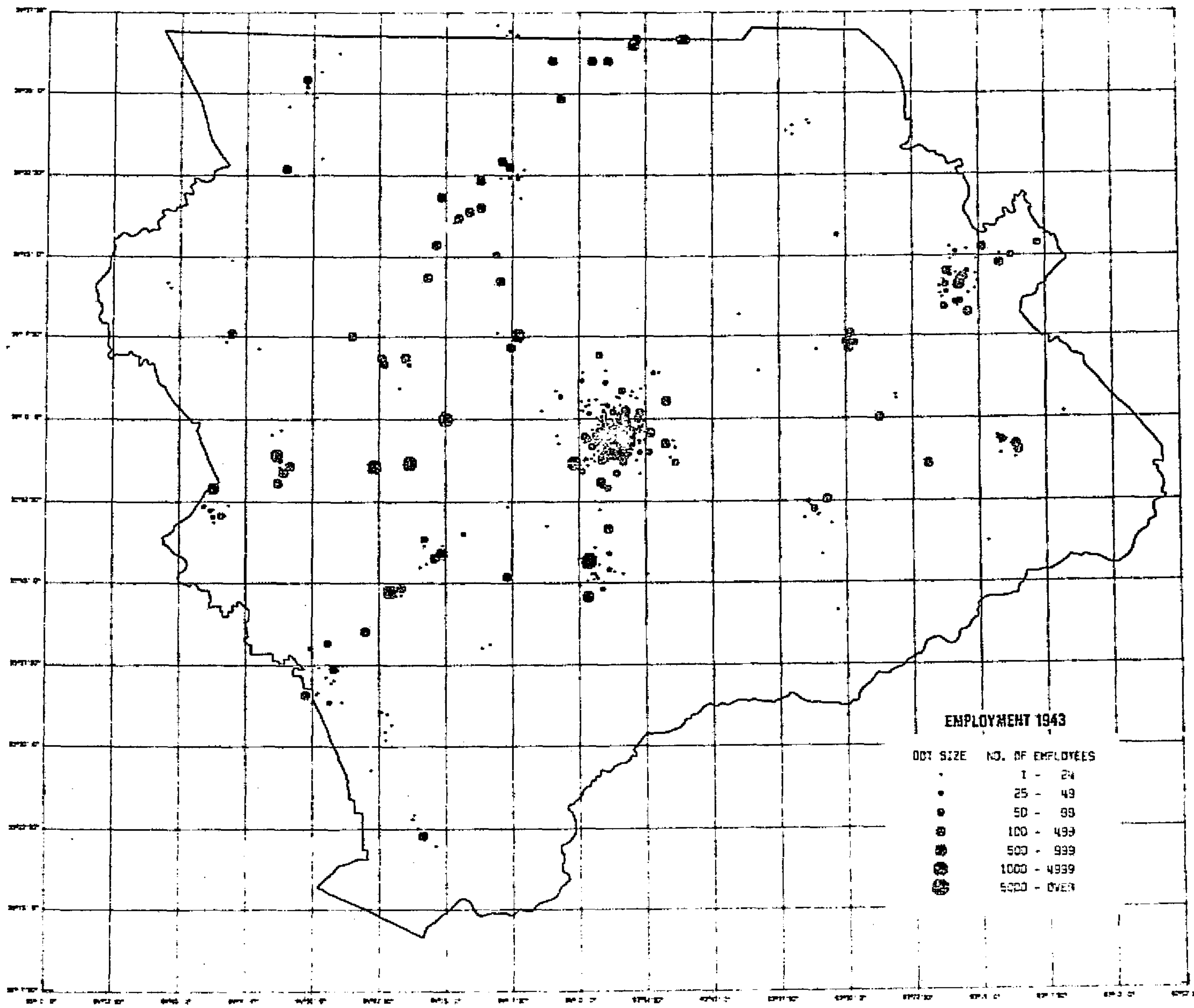

EMPLOYMENT 1943
DOT SIZE NO. OF EMPLOYEES
1 - 24
25 - 49
50 - 99
100 - 499
500 - 999
1000 - 4999
5000 - OVER

Figure 7

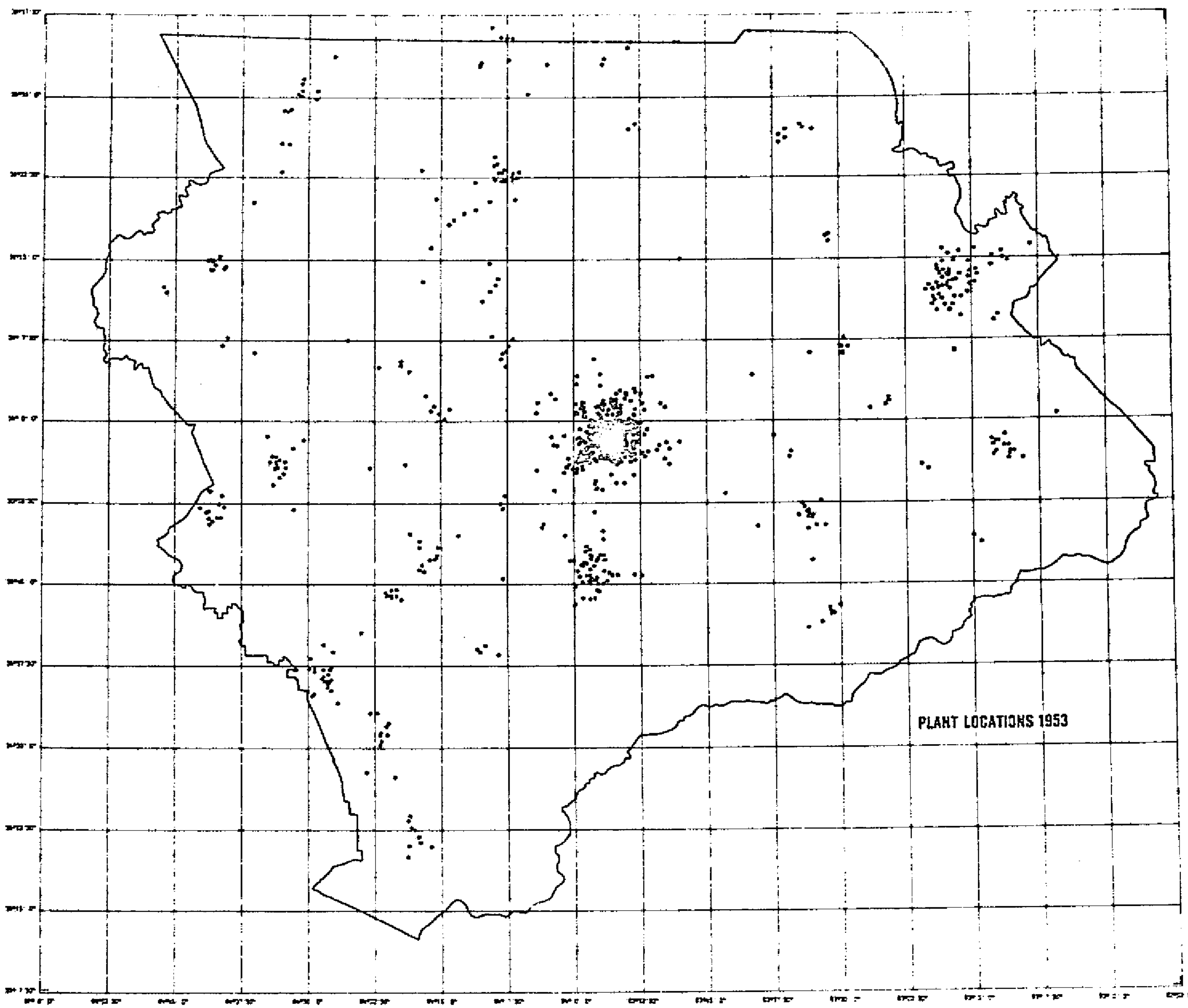
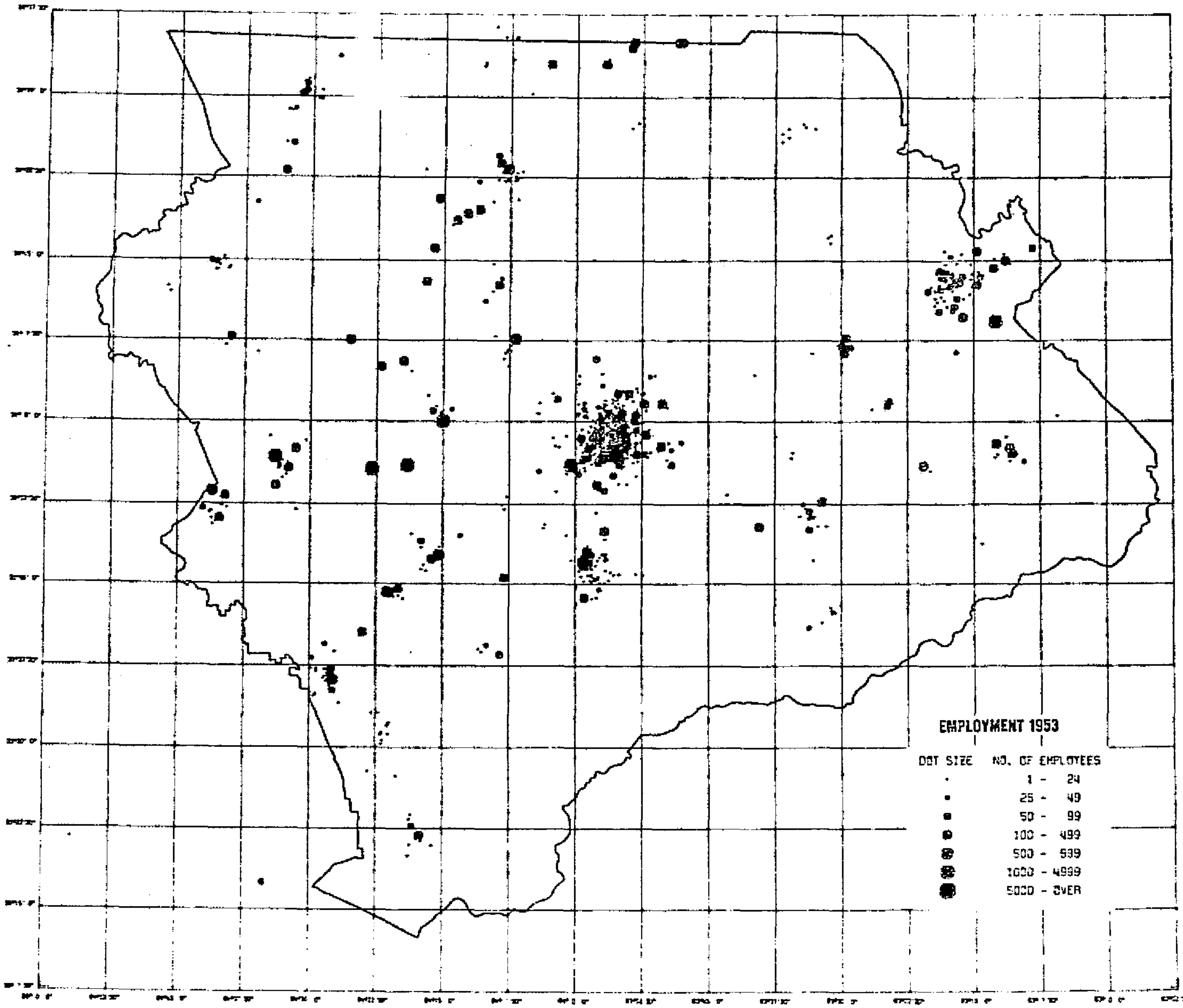



Figure 8.


EMPLOYMENT 1953
DOT SIZE NO. OF EMPLOYEES
1 - 24
25 - 49
50 - 99
100 - 499
500 - 999
1000 - 4999
5000 - OVER
Figure 9.

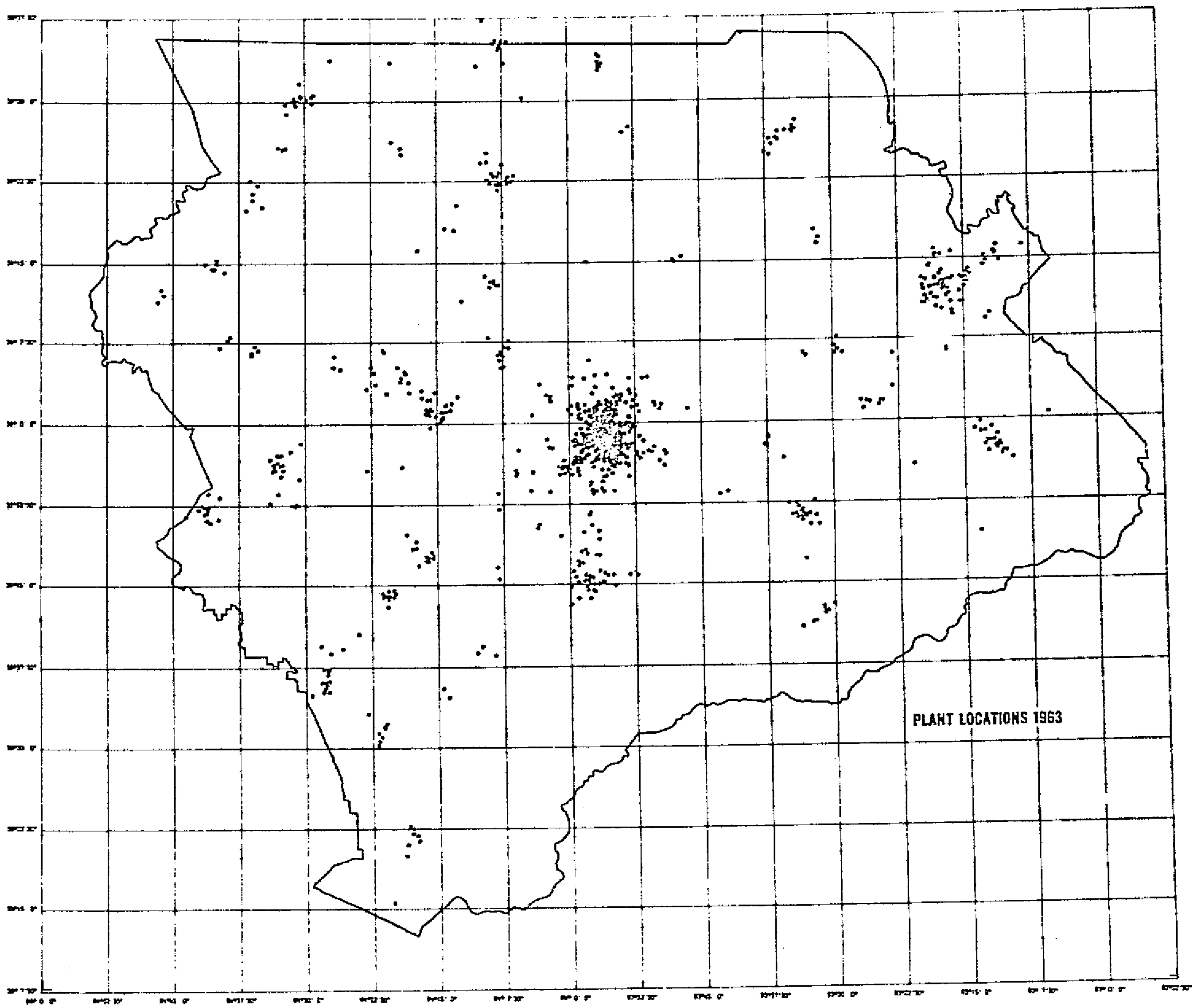



Figure 10.

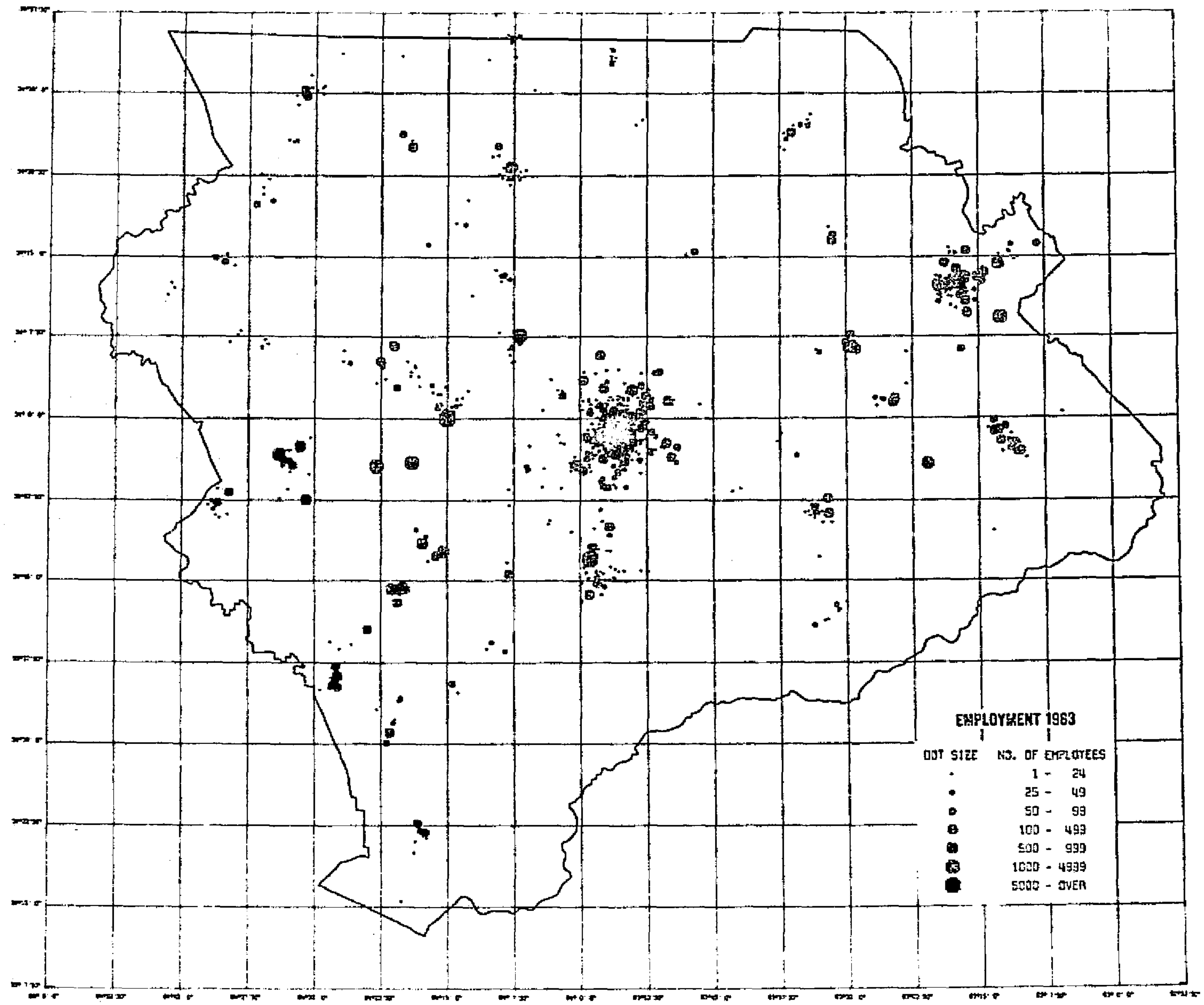

EMPLOYMENT 1963
DOT SIZE NO. OF EMPLOYEES
1 - 24
25 - 49
50 - 99
100 - 499
500 - 999
1000 - 4999
5000 - OVER

Figure 11.

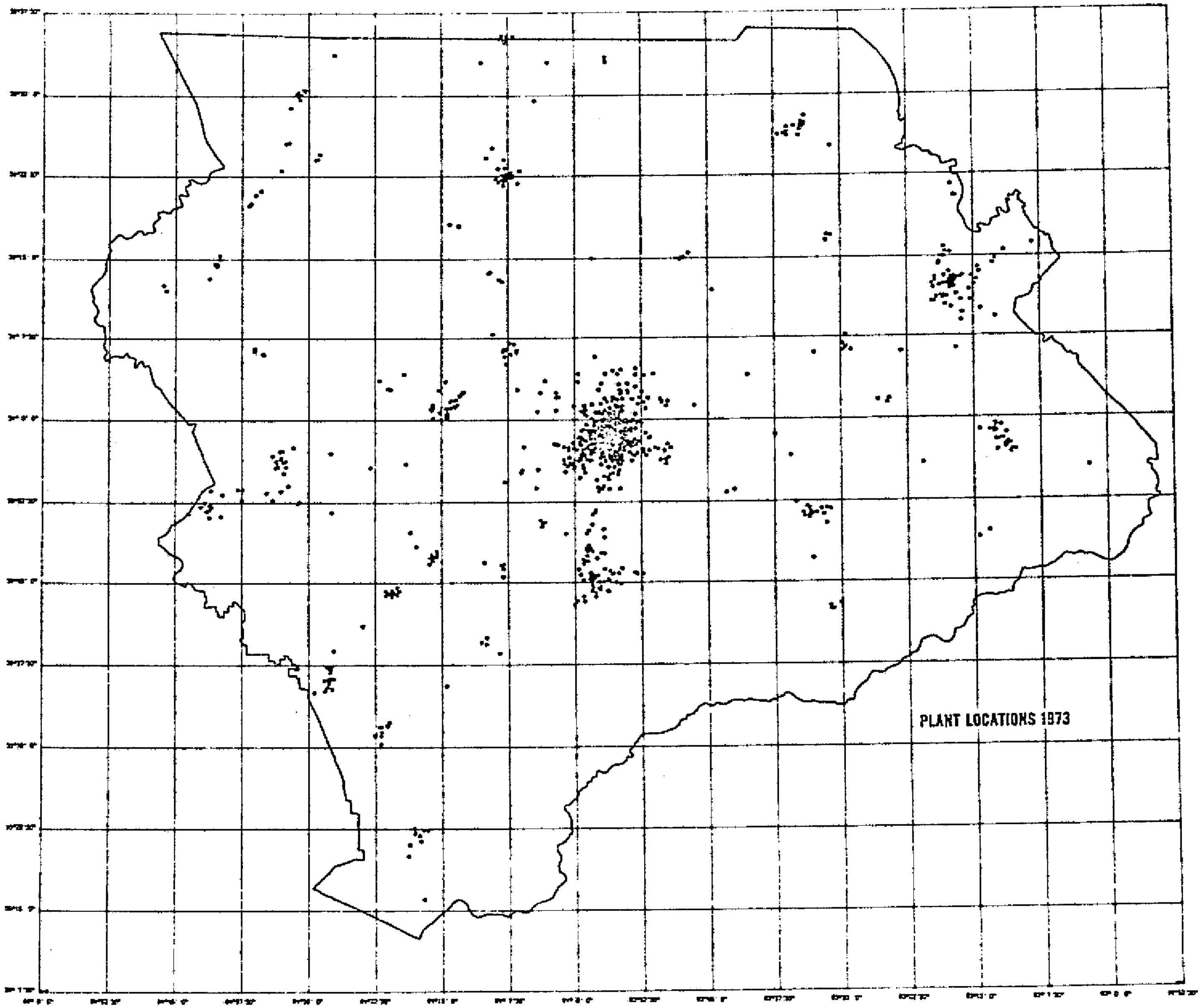



Figure 12.

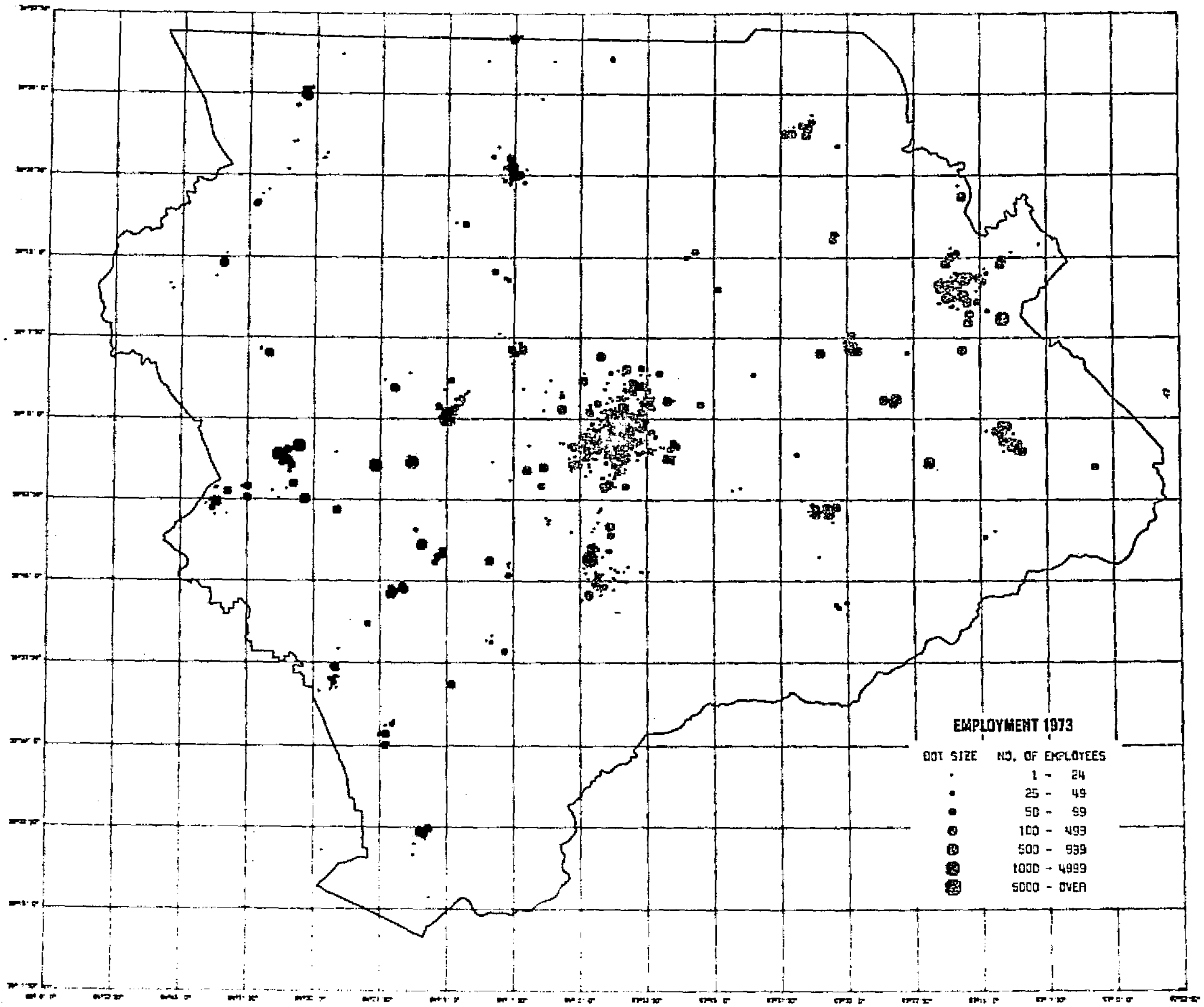

EMPLOYMENT 1973
DOT SIZE
NO. OF EMPLOYEES
1 - 24
25 - 49
50 - 99
100 - 499
500 - 999
1000 - 4999
5000 - OVER

Figure 13.

A number of variables may be eliminated as not related to the site-selection process while others can be combined with other variables. After considerable study the following list of variables was developed to be used in a survey of the site conditions of past industrial location events. Selection was based upon the relevance of the variable to industrial site-selection and the ability to quantify the variable either from aerial photography or from extant data sources. The variables are listed below:

I. Site Preparation Cost

a. Slope of land
b. Drainage
c. Clearing-cover conditions

II. Market Price of Land

a. Distance to center of town
b. Distance to nearest major thoroughfare
c. Density of urban use in immediate vicinity
d. Overall rating of price of land from 1 to 10

III. Proximity to Work Force

a. Proportion of nearest city within 2-1/2 miles
b. Population of nearest community

IV. Transportation Accessibility

a. Distance to major highway
b. Distance to secondary road
c. Distance to rail
d. Distance to airport
e. Waterway service
f. Distance to nearest Interstate interchange
g. Overall quality of accessibility from 1 to 10

V. Utilities

a. Water available
b. Gas available
c. Sewerage available

VI. Compatibility with Existing Land Uses

a. Did community have zoning at time of location?
b. Was site zoned for industry?
c. Was zone changed to accept industry?
d. Was industry already in immediate area?
e. Overall rating of contiguous land use compatibility

VII. Neighborhood or Community Attractiveness and Amenities

a. Condition of neighborhood
b. Density of land use in immediate vicinity
c. Nearby community services

VIII. Industrial Park Space

a. Was the site in an industrial park?
b. Overall rating of the quality of park?

Additional Data Collected

a. Proximity of site to Knoxville
b. Amount of other industry located nearby at time of event
c. Was building already there?

This list may omit variables which should be considered and, therefore, should not be considered exhaustive. At the same time, however, it is anticipated that in measuring the importance of each variable some may be eliminated thus further reducing the site-selection variables.

## Data Collection

Those familiar with land use models are well aware of problems in acquiring reliable and objectively derived data to characterize land use development processes. To overcome this problem, this research effort has depended upon the use of historical and current aerial photography rather than survey data or "expert" opinion. The use of aerial photography to analyze land use change and to structure a simulation

algorithm is unusual but not without precedent. The studies conducted at Harvard University, Graduate School of Design, Department of Landscape Architecture, and the University of North Carolina, Department of Urban and Regional Planning are examples.[5] The distinction of this study is the manner in which data derived from the aerial photography are analyzed statistically to define relevant criteria.

To illustrate the use of the aerial photography in this analysis two stereo images have been included (Figs. 52 and 53) illustrating the before and after scenes of an industrial location event. The site located near Harriman, Tennessee, was occupied in 1966 by the Beta-Tek Inc. which manufactures electrical machinery. Present employment is approximately 130 people. The first stereo image indicates the condition of the site and surroundings as of March 30, 1958 (TVA photography) while the second stereo image indicates the conditions as of March 22, 1974 (NASA photography).

Obviously, aerial photography cannot be a sole source of data. Most planning agencies maintain data files pertaining to industrial park development, utility services, and land use plans which may be used to augment data derived from aerial photography. Much of these data have been compiled at Oak Ridge National Laboratory and were utilized in this analysis.

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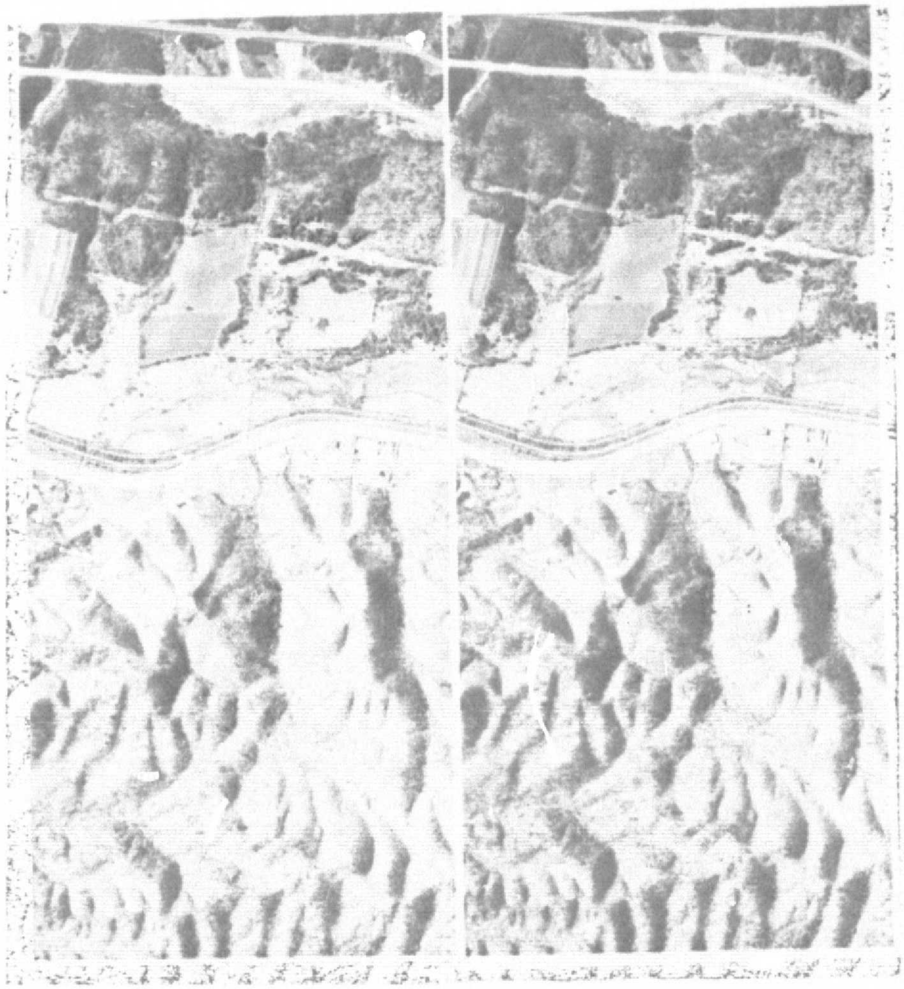
[5] For example, see: Carl Steintz and Peter Rogers, *A System Analysis Model of Urbanization and Change: An Experiment in Interdisciplinary Education* (Cambridge: M.I.T. Press, 1971); and Thomas G. Donnelly, F. Stuart Chapin, and Shirley F. Weiss, *A Probabilistic Model for Residential Growth* (Chapel Hill: University of North Carolina, Institute for Research in Social Science, 1964).

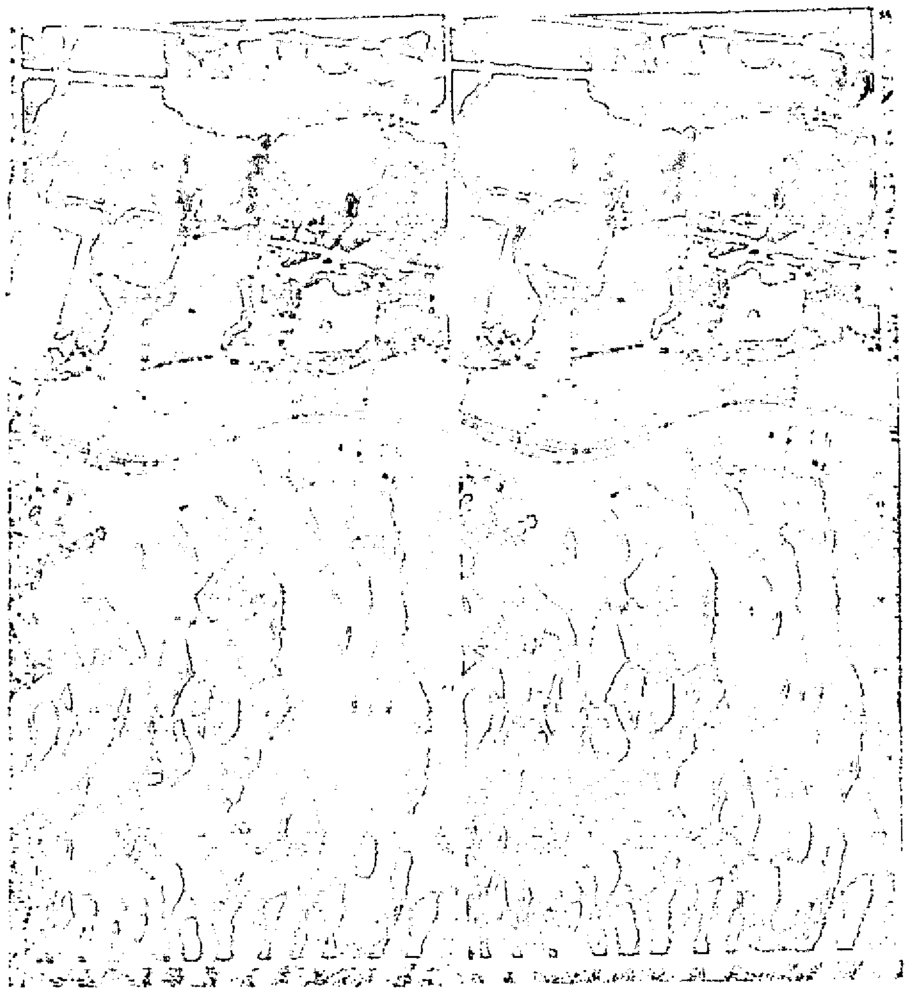
1958 - STEREO IMAGE OF BETA-TEK INDUSTRIAL SITE
(TVA - 1:30,000)

Figure 14.



1974 - STEREO IMAGE OF BETA-TEK INDUSTRIAL SITE
(NASA - 1:24,000)

Figure 15.



1974 - STEREO IMAGE OF BETA-TEK INDUSTRIAL SITE
(NASA - 1:24,000)

Figure 15.

The ORNL data base contains information concerning the general location of existing industry within the ETDD region; the date an industry located in the region; the number of employees initially employed and presently employed; and the primary and secondary SIC designation of each industry. Using NASA and TVA aerial photography, census materials and interviews with local citizens, spatial conditions which existed prior to the time of the industrial location event were reconstructed. Location events occurring before 1950 were not analyzed. However, industries which expanded or relocated after 1950 were included. Most of the location events analyzed occurred after 1956, the year Congress passed the National Defense Highway Act creating the Interstate Highway System. It is thought that many of the locational decisions after 1956 (and perhaps before) were partially affected by knowledge of the location of Interstate highways.

A minimum sample size of 157 industries was considered to be adequate to determine the statistical significance of the variables believed to be associated with industrial site selection processes. (This represents a 15 percent sample of the total number of industries presently within ETDD and a 33 percent sample of the industries which have located in ETDD since 1950. Also, 50 percent of those industries located in the area since 1964 and 25 percent since 1968.) Industries were selected in a manner to maintain a homogenous mixture and to assure an adequate regional sample. Efforts were also made to maintain a sampling balance between metropolitan and rural industry according to plant distribution.

## Statistical Procedures

As the study progressed and the complexities of the industrial site selection process were recognized, it was decided that simple statistical procedures would not be sufficient to "untangle" the interacting variables to produce meaningful answers. Therefore, a multivariate procedure (specifically factor analysis) was chosen to describe interconnection of the variables that appear to be meaningfully related to the industrial site selection process.

There are several reasons for this decision. Among many multivariate procedures, factor analysis is distinguished by its data-reduction capabilities. "Given an array of correlation coefficients for a set of variables, factor-analytic techniques enable us to see whether some underlying pattern of relationships exists such that the data may be 'rearranged' or 'reduced' to a smaller set of factors or components that may be taken as source variables accounting for the observed interrelations in the data."[5] Common applications of the method may be grouped into one of the following categories: "(1) exploratory uses — the exploration and detection of patterning of variables with a view of the discovery of new concepts and a possible reduction of data; (2) confirmatory uses — the testing of hypotheses about the structuring of variables in terms of the expected number of significant factors and factor loadings; and (3) uses as a measuring device — the construction of indices to be used as new variables in later analysis."[6]

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[5]Norman Nie, Dale H. Bent, and C. Haddie Hull, *SPSS: Statistical Package for the Social Sciences* (New York: McGraw-Hill Book Company, 1970), p. 209.

[6]Ibid.

Most studies utilizing factor analysis employ the technique for exploratory purposes. Its use in this study was: (1) to reduce the original set of variables, (2) to determine if the variables group as previously conceived, and (3) to define more succinct indexes which describe the site-selection process.

"The beauty of factor analysis is that it takes thousands...of measurements...and resolves them into distinct patterns of occurrence."[7] For example, the data matrix in this study contains (150 industries x 30 variables) 4500 pieces of information. Factor analysis permits one to identify patterns of relationships among these data which would be impossible for the human mind alone.

Factor analysis begins with the construction of a correlation matrix, usually through the use of Pearson product-moment correlation coefficients. In setting up the correlation matrix, the user of factor analysis has some alternatives; he may calculate correlations among variables (or attributes), in which case the approach is called R-factor analysis, or he may calculate "association" between individuals or objects, which is known as Q-factor analysis. We are primarily concerned with R-factor analysis in this study as the desire is to group or eliminate variables.[8]

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[7] R. J. Rummel, "Understanding Factor Analysis," *The Journal of Conflict Resolution*, XI (December 1967), p. 445.

[8] John P. Van de Geer, *Introduction to Multivariate Analysis for the Social Sciences* (San Francisco: W. H. Freeman and Company, 1971), pp. 128-129. Recently studies have varied from the use of product-moment correlations to include rank-correlation coefficients and, in some cases, frequency data.

The final step in factor analysis involves the rotation of the p-dimensional axis to simplify the identification and naming of the factors. The options involve either an orthogonal rotation method or an oblique rotational method. "Orthogonal rotation is mathematically simpler to handle, while oblique factors are empirically more realistic."[9] The mathematical distinction is that orthogonal factors are uncorrelated, while oblique factors may be correlated. For this study an orthogonal rotation was utilized called VARIMAX which centers on simplifying the columns of a factor matrix — that is, the inferred factors.

The results of the factor analysis of measurements obtained on 30 variables for 157 industries along with simple statistical descriptions of the variables are presented in the next section.

[9]Nie and others, p. 212.

# IV. EMPIRICAL ANALYSIS OF INDUSTRIAL LOCATION EVENTS

This section presents the results of an analysis of variables believed to be related to industrial site-selection events which have occurred in the ETDD region since 1950. Descriptive statistics of each variable are presented first, followed by the results of the factor analysis.

## Descriptive Statistics

This analysis made use of a system of computer programs called the *Statistical Package for the Social Sciences* (SPSS) designed by Norman Nie and Dale Brent.[1] These package programs permit a variety of analysis procedures and means for presentation of results.

### Description of Sample

This analysis is based upon a sample of 157 industries, 15 percent of the total number of industries in the region. Fifty percent of these industries located in the region since 1964 and 25 percent since 1968. Approximately 50 percent of the industries sampled had 50 employees or less, with 80 percent of the industries sampled having less than 200 employees. Only 2 percent of the sample had over 1000 employees.

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[1]Norman Nie, Dale H. Bent, and C. Hadlai Hull, *SPSS: Statistical Package for the Social Sciences* (New York: McGraw-Hill Book Company, 1970).

Table 8 presents a breakdown of the sample by SIC number relative to the total number of industries in the ETDD region. The mixture is proportional to the total regional mixture of industries considering some SIC categories have few new industries.

Description of Variable Measurements

For each of the 157 industrial site-selection events analyzed, measurements were obtained for 30 variables. The tables which follow provide a statistical summary of these data. Appendix A contains a sample survey form used to record these measurements. Ordinal scores from one to ten were used for variables which required measurements of absolute or relative value: 1 = lowest value, and 10 = greatest value. Measurements requiring yes or no answers were scored: 1 = yes and 10 = no.

Measurement of the slope and drainage characteristics obtained for the industrial sample are presented in Tables 9 and 10 respectively. Flat sites (less than 1% slope) were scored 1 and steep slope sites (30% or greater) were scored 10. Preference for gently sloping terrain is obvious from the data. These sites, however, were not always located in extensive flat areas. Many small local industries seem to prefer small flat sites which may be surrounded by steeper sloping land. Drainage conditions were assessed on the basis of (1-3) = no water problems, (4-7) = some problems, and (8-10) = frequent problems. Most of the industrial sites examined appeared to have few or no problems with flooding.

Cover conditions present few problems in the site selection process simply because of the amount of land available which has already been

| Industry Type | Number in Sample | Total Number of ETDD Industries in 1973[2] |
|---|---|---|
| SIC 20 - Food | 15 | 112 |
| SIC 22 - Textile | 5 | 40 |
| SIC 23 - Clothing | 9 | 67 |
| SIC 24 - Lumber | 12 | 110 |
| SIC 25 - Furniture | 25 | 64 |
| SIC 26 - Paper | 4 | 7 |
| SIC 27 - Printing | 6 | 95 |
| SIC 28 - Chemical | 7 | 42 |
| SIC 29 - Petroleum | 1 | 10 |
| SIC 30 - Rubber & Plastic | 7 | 14 |
| SIC 31 - Leather | 2 | 15 |
| SIC 32 - Stone, Clay | 13 | 86 |
| SIC 33 - Prim. Metals | 6 | 18 |
| SIC 34 - Fab. Metals | 15 | 86 |
| SIC 35 - Mach. (Ex. Elec.) | 7 | 75 |
| SIC 36 - Elec. Mach. | 8 | 25 |
| SIC 37 - Trans. | 5 | 20 |
| SIC 38 - Instruments | 1 | 21 |
| SIC 39 - Misc. | 7 | 57 |
| Totals | 157 | 975 |

DISTRIBUTION OF SAMPLE BY SIC CATEGORY

TABLE 8

[2]The total number of industries in 1974 is 1002. These figures are based upon a census conducted in 1972-73.

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 37 | 23.6 | 23.6 | 23.6 |
| 2.00 | 33 | 21.0 | 21.0 | 44.6 |
| 3.00 | 35 | 22.3 | 22.3 | 66.9 |
| 4.00 | 26 | 16.6 | 16.6 | 83.4 |
| 5.00 | 15 | 9.6 | 9.6 | 93.0 |
| 6.00 | 6 | 3.8 | 3.8 | 96.8 |
| 7.00 | 1 | 0.6 | 0.6 | 97.5 |
| 8.00 | 2 | 1.3 | 1.3 | 98.7 |
| 9.00 | 2 | 1.3 | 1.3 | 100.0 |
| 0.0 | 0 | 0.0 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 2.955 Mode 1.000 Median 2.743 Kurtosis 1.186

Std Dev 1.715 Skewness 1.003 Variance 2.940

Missing Observations 0

VARIABLE - SLOPE OF LAND

TABLE 9

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 113 | 72.0 | 72.0 | 72.0 |
| 2.00 | 24 | 15.3 | 15.3 | 87.3 |
| 3.00 | 12 | 7.6 | 7.6 | 94.9 |
| 4.00 | 2 | 1.3 | 1.3 | 96.2 |
| 5.00 | 3 | 1.9 | 1.9 | 98.1 |
| 6.00 | 1 | 0.6 | 0.6 | 98.7 |
| 7.00 | 1 | 0.6 | 0.6 | 99.4 |
| 8.00 | 1 | 0.6 | 0.6 | 100.0 |
| 0.0 | 0 | 0.0 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.535 Mode 1.000 Median 0.0 Kurtosis 10.739

Std Dev 1.141 Skewness 3.031 Variance 1.302

Missing Observations 0

VARIABLE - DRAINAGE

TABLE 10

cleared for agriculture. Sixty-three percent of the industries located on sites with no clearing problems at all (Table 11).

Measurements of the distance to the center of town were scored according to the position of the site relative to the urban developed area. For example, sites in or near the center of town were scored from 1-3, suburban or urban fringe sites from 4-7, and sites in rural or remote areas from 8-10. Suburban and urban fringe areas seem to be the preferred location of those industries sampled (Table 12).

Distance to the nearest major throughfare was included to measure the importance of proximity to main streets in the CBD or major routes radiating from the CBD. Sites adjacent to major throughfares were scored 1. Sites displaced 2 or 3 blocks were scored 2 to 4. Sites remote from major urban throughfares were scored 6-10. Most of the sites surveyed were located just off major urban throughfares (Table 13).

Measurements for the density of land use in the immediate vicinity of the site have a double-modal distribution reflecting industry preference for two types of sites, urban fringe sites of medium density, and historical industrial sites situated near the CBD (Table 14).

Estimates of the unit price of land were based upon the location of the site relative to the CBD and major thoroughfares. The distribution is flat-topped (platykurtic) indicating industry prefers a broad range in land values (Table 15). This agrees with the theoretical statements noted in Chapter II.

Measurements of the proportion of urban area within 2-1/2 miles of the industrial site were included in the survey more for future

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 95 | 60.5 | 63.3 | 63.3 |
| 2.00 | 11 | 7.0 | 7.3 | 70.7 |
| 3.00 | 8 | 5.1 | 5.3 | 76.0 |
| 4.00 | 7 | 4.5 | 4.7 | 80.7 |
| 5.00 | 2 | 1.3 | 1.3 | 82.0 |
| 6.00 | 7 | 4.5 | 4.7 | 86.7 |
| 7.00 | 7 | 4.5 | 4.7 | 91.3 |
| 8.00 | 5 | 3.2 | 3.3 | 94.7 |
| 9.00 | 5 | 3.2 | 3.3 | 98.0 |
| 10.00 | 3 | 1.9 | 2.0 | 100.0 |
| 0.0 | 7 | 4.5 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 2.567 Mode 1.000 Median 0.0 Kurtosis 0.927

Std Dev 2.597 Skewness 1.516 Variance 6.744

Missing Observations 7

VARIABLE - CLEARING—COVER CONDITIONS

TABLE 11

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 12 | 7.6 | 7.7 | 7.7 |
| 2.00 | 12 | 7.6 | 7.7 | 15.4 |
| 3.00 | 23 | 14.6 | 14.7 | 30.1 |
| 4.00 | 12 | 7.6 | 7.7 | 37.8 |
| 5.00 | 29 | 18.5 | 18.6 | 56.4 |
| 6.00 | 12 | 7.6 | 7.7 | 64.1 |
| 7.00 | 17 | 10.8 | 10.9 | 75.0 |
| 8.00 | 14 | 8.9 | 9.0 | 84.0 |
| 9.00 | 14 | 8.9 | 9.0 | 92.9 |
| 10.00 | 11 | 7.0 | 7.1 | 100.0 |
| 0.0 | 1 | 0.6 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 5.365 Mode 5.000 Median 5.155 Kurtosis -1.027

Std Dev 2.650 Skewness 0.107 Variance 7.020

Missing Observations 1

VARIABLE - DISTANCE TO CENTER OF TOWN

TABLE 12

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 49 | 31.2 | 31.8 | 31.8 |
| 2.00 | 83 | 52.9 | 53.9 | 85.7 |
| 3.00 | 18 | 11.5 | 11.7 | 97.4 |
| 5.00 | 2 | 1.3 | 1.3 | 98.7 |
| 6.00 | 1 | 0.6 | 0.6 | 99.4 |
| 10.00 | 1 | 0.6 | 0.6 | 100.0 |
| 0.0 | 3 | 1.9 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.916 Mode 2.000 Median 1.837 Kurtosis 24.461

Std Dev 1.035 Skewness 3.789 Variance 1.071

Missing Observations 3

VARIABLE - DISTANCE TO NEAREST MAJOR THROUGHFARE

TABLE 13

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 28 | 17.8 | 17.9 | 17.9 |
| 2.00 | 16 | 10.2 | 10.3 | 28.2 |
| 3.00 | 29 | 18.5 | 18.6 | 46.8 |
| 4.00 | 13 | 8.3 | 8.3 | 55.1 |
| 5.00 | 6 | 3.8 | 3.8 | 59.0 |
| 6.00 | 14 | 8.9 | 9.0 | 67.9 |
| 7.00 | 16 | 10.2 | 10.3 | 78.2 |
| 8.00 | 12 | 7.6 | 7.7 | 85.9 |
| 9.00 | 17 | 10.8 | 10.9 | 96.8 |
| 10.00 | 5 | 3.2 | 3.2 | 100.0 |
| 0.0 | 1 | 0.6 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 4.641 Mode 3.000 Median [illegible] Kurtosis -1.273

Std Dev 2.878 Skewness 0.2[illegible] Variance 8.283

Missing Observations 1

VARIABLE - DENSITY OF LAND USE IN IMMEDIATE VICINITY

TABLE 14

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 4 | 2.5 | 2.6 | 2.6 |
| 2.00 | 13 | 8.3 | 8.4 | 11.0 |
| 3.00 | 17 | 10.8 | 11.0 | 22.1 |
| 4.00 | 17 | 10.8 | 11.0 | 33.1 |
| 5.00 | 16 | 10.2 | 10.4 | 43.5 |
| 6.00 | 24 | 15.3 | 15.6 | 59.1 |
| 7.00 | 30 | 19.1 | 19.5 | 78.6 |
| 8.00 | 21 | 13.4 | 13.6 | 92.2 |
| 9.00 | 11 | 7.0 | 7.1 | 99.4 |
| 10.0 | 1 | 0.6 | 0.6 | 100.0 |
| 0.0 | 3 | 1.9 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 5.584 Mode 7.000 Median 5.917 Kurtosis -0.934

Std Dev 2.210 Skewness -0.268 Variance 4.885

Missing Observations 3

VARIABLE - RATING OF PRICE OF LAND

TABLE 15

analysis purposes than for the purpose of this study. Additional data necessary to give the measure meaning were not digitized at a fine enough scale at the time of this study. Census variables such as average value of housing, percent of workers in manufacturing, median family income, etc., are presently being digitized by census tract, enumeration districts, or aggregates of enumeration districts, called parcels. Approximately 189 variables are being stored and the additional programming assistance to acquire access to them was not available.

Knowledge of the sample pattern permits one to interpret the frequency distribution in Table 16. Forty-five percent of the sample industrial sites were located in the Knoxville region and approximately 70 percent of these were located on the fringe of Knoxville. Because of the size of Knoxville, the 2-1/2 mile radius rarely encircled more than 40 percent (score = 4) of the urbanized area.[3] The remainder of the sample included sites near small communities and frequently the 2-1/2 mile circle would include most of the urbanized area (score = 8-10).

Distance to major highway was measured differently from distance to major thoroughfare. This measure was included to determine if proximity to federal and state highways functioning at the time of the location event affect site choices differently than proximity to major thoroughfares. Most of the sites were located close to major highways

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[3]The 2-1/2 mile radius was selected on the basis of two considerations. If proximity to a suitable work force has any effect upon the site selection process, it was decided that 2-1/2 miles would be approximately the maximum distance which could be considered convenient to the work place. Secondly, the 2-1/2 mile dimension conveniently integrates with the cell dimension to be used in the ORNL land use model.

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 46 | 29.3 | 29.3 | 29.3 |
| 2.00 | 15 | 9.6 | 9.6 | 38.9 |
| 3.00 | 6 | 3.8 | 3.8 | 42.7 |
| 4.00 | 22 | 14.0 | 14.0 | 56.7 |
| 5.00 | 7 | 4.5 | 4.5 | 61.1 |
| 6.00 | 4 | 2.5 | 2.5 | 63.7 |
| 7.00 | 5 | 3.2 | 3.2 | 66.9 |
| 8.00 | 15 | 9.6 | 9.6 | 76.4 |
| 9.00 | 13 | 8.3 | 8.3 | 84.7 |
| 10.00 | 24 | 15.3 | 15.3 | 100.0 |
| 0.0 | 0 | 0.0 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 4.796 Mode 1.000 Median 4.023 Kurtosis -1.490

Std Dev 3.469 Skewness 0.310 Variance 12.035

Missing Observations 0

VARIABLE - PROPORTION OF URBAN AREA
WITHIN TWO AND A HALF MILES

TABLE 16

(Table 17); however, 10 sites were located in areas 10 or more miles from a major highway.

Distance to secondary road was intended to measure the importance of egress and ingress to the plant site. It was believed that most industries would prefer sites which did not require plant traffic to interact directly with a major highway. The distribution in Table 18 indicates response to this factor.

Although 60 percent of the sites examined were adjacent to railroads, the importance of rail accessibility in current location decisions is questionable. Many of the sites occupied in the last decade were inaccessible to rail service (score = 10) or they could be served only with great difficulty (score = 5-9) (Table 19).

Distance to waterway was considered to have potential site importance to only a few industry types. This study, however, is concerned with the development of a general site selection algorithm. Consequently distance to waterway was included. Sixty percent of the sites included in the study were inaccessible to TVA waterways (Table 20) indicating the importance of this factor to be relatively low for most industry types. Some of the sites near Knoxville, Lenoir City, and Loudon were close to public docks and, therefore, received higher accessibility values, but only three sites surveyed had dock-side access at the plant.

Commercial airport accessibility may be considered as both a regional influence and a local influence in industrial site selection decisions particularly in the case of small to medium-sized industries. The effect of small airports in the decision process was not considered due to the widespread distribution of private and municipal airports

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 36 | 22.9 | 22.9 | 22.9 |
| 2.00 | 101 | 64.3 | 64.3 | 87.3 |
| 3.00 | 10 | 6.4 | 6.4 | 93.6 |
| 5.00 | 2 | 1.3 | 1.3 | 94.9 |
| 10.0 | 8 | 5.1 | 5.1 | 100.0 |
| 0.0 | 0 | 0.0 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 2.280 Mode 2.000 Median 1.921 Kurtosis 11.143

Std Dev 1.901 Skewness 3.414 Variance 3.613

Missing Observations 0

VARIABLE - DISTANCE TO MAJOR HIGHWAY

TABLE 17

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 146 | 93.0 | 93.0 | 93.0 |
| 2.00 | 8 | 5.1 | 5.1 | 98.1 |
| 3.00 | 2 | 1.3 | 1.3 | 99.4 |
| 5.00 | 1 | 0.6 | 0.6 | 100.0 |
| 0.0 | 0 | 0.0 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.102 Mode 1.000 Median 1.0 Kurtosis 41.611

Std Dev 0.441 Skewness 5.881 Variance 0.195

Missing Observations 0

VARIABLE - DISTANCE TO SECONDARY ROAD

TABLE 18

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 80 | 51.0 | 51.0 | 51.0 |
| 2.00 | 17 | 10.8 | 10.8 | 61.8 |
| 3.00 | 6 | 3.8 | 3.8 | 65.6 |
| 4.00 | 5 | 3.2 | 3.2 | 68.8 |
| 5.00 | 2 | 1.3 | 1.3 | 70.1 |
| 6.00 | 5 | 3.2 | 3.2 | 73.2 |
| 7.00 | 3 | 1.9 | 1.9 | 75.2 |
| 8.00 | 12 | 7.6 | 7.6 | 82.8 |
| 9.00 | 1 | 0.6 | 0.6 | 83.4 |
| 10.00 | 26 | 16.6 | 16.6 | 100.0 |
| 0.0 | 0 | 0.0 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 3.682 Mode 1.000 Median 1.3 Kurtosis -0.950

Std Dev 3.563 Skewness 0.886 Variance 12.693

Missing Observations 0

VARIABLE - DISTANCE TO RAILWAY

TABLE 19

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 3 | 1.9 | 1.9 | 1.9 |
| 2.00 | 8 | 5.1 | 5.1 | 7.1 |
| 3.00 | 5 | 3.2 | 3.2 | 10.3 |
| 4.00 | 5 | 3.2 | 3.2 | 13.5 |
| 5.00 | 6 | 3.8 | 3.8 | 17.3 |
| 6.00 | 3 | 1.9 | 1.9 | 19.2 |
| 7.00 | 5 | 3.2 | 3.2 | 22.4 |
| 8.00 | 14 | 8.9 | 9.0 | 31.4 |
| 9.00 | 10 | 6.4 | 6.4 | 37.8 |
| 10.00 | 97 | 61.8 | 62.2 | 100.0 |
| 0.0 | 1 | 0.6 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 8.391 Mode 10.000 Median 9.3 Kurtosis 0.967

Std Dev 2.646 Skewness -1.534 Variance 7.001

Missing Observations 1

VARIABLE - DISTANCE TO WATERWAY

TABLE 20

throughout the region. The frequency distribution probably reflects the regional spread of industry more than the importance of the factor in the site selection process (Table 21).

Distance to Interstate highway interchange measures the importance that proximity to the Interstate system may have on the site selection process. Sites within two miles were scored a 1; sites farther away were scored on the basis of 2-mile increments for each number assigned. Approximately 90 percent of the industries surveyed have located or relocated since the Interstate highway system was created in 1956. Eighty-eight percent of the sites were within eight miles of an interchange (Table 22).

Two measures of the overall quality of accessibility were included in this analysis to determine if a collective measure of accessibility would be significantly different from individual measures of accessibility and to determine if the overall quality of the accessibility has significantly changed since the location event. The latter may indicate whether industry location may influence future transportation improvements. The measures were overall quality of accessibility then (Table 23) and overall quality of accessibility now (Table 24). Some improvement can be noted (the mean distance reduced from 4.55 to 4.10). Overall accessibility now was not incorporated into the factor analysis.

Tables 25, 26, and 27 reflect measurements of the availability of utilities at the site before the industrial location event. In 90 percent of the cases, both water and gas were available at the site and in approximately 70 percent of the cases municipal sewage service was available. It was noted that many industries locate beyond the city limits to avoid

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 1 | 0.6 | 0.6 | 0.6 |
| 2.00 | 8 | 5.1 | 5.1 | 5.8 |
| 3.00 | 32 | 20.4 | 20.5 | 26.3 |
| 4.00 | 14 | 8.9 | 9.0 | 35.3 |
| 5.00 | 12 | 7.6 | 7.7 | 42.9 |
| 6.00 | 3 | 1.9 | 1.9 | 44.9 |
| 7.00 | 2 | 1.3 | 1.3 | 46.2 |
| 8.00 | 6 | 3.8 | 3.8 | 50.0 |
| 9.00 | 2 | 1.3 | 1.3 | 51.3 |
| 10.00 | 76 | 48.4 | 48.7 | 100.0 |
| 0.0 | 1 | 0.6 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 6.968 Mode 10.000 Median 8.500 Kurtosis -1.708

Std Dev 3.236 Skewness -0.289 Variance 10.470

Missing Observations 1

VARIABLE - DISTANCE TO AIRPORT

TABLE 21

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 58 | 36.9 | 37.4 | 37.4 |
| 2.00 | 21 | 13.4 | 13.5 | 51.0 |
| 3.00 | 48 | 30.6 | 31.0 | 81.9 |
| 4.00 | 10 | 6.4 | 6.5 | 88.4 |
| 6.00 | 6 | 3.8 | 3.9 | 92.3 |
| 8.00 | 2 | 1.3 | 1.3 | 93.5 |
| 10.00 | 10 | 6.4 | 6.5 | 100.0 |
| 0.0 | 2 | 1.3 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 2.813 Mode 1.000 Median 2.429 Kurtosis 3.285

Std Dev 2.352 Skewness 1.927 Variance 5.530

Missing Observations 2

VARIABLE - DISTANCE TO NEAREST INTERSTATE

TABLE 22

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 1 | 0.6 | 0.6 | 0.6 |
| 2.00 | 14 | 8.9 | 9.1 | 9.7 |
| 3.00 | 24 | 15.3 | 15.6 | 25.3 |
| 4.00 | 24 | 15.3 | 15.6 | 40.9 |
| 5.00 | 60 | 38.2 | 39.0 | 79.9 |
| 6.00 | 20 | 12.7 | 13.0 | 92.9 |
| 7.00 | 4 | 2.5 | 2.6 | 95.5 |
| 8.00 | 7 | 4.5 | 4.5 | 100.0 |
| 0.0 | 3 | 1.9 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 4.552 Mode 5.000 Median 4.733 Kurtosis -0.007

Std Dev 1.469 Skewness 0.084 Variance 2.157

Missing Observations 3

VARIABLE - OVERALL QUALITY OF ACCESSIBILITY--THEN

TABLE 23

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 5 | 3.2 | 3.2 | 3.2 |
| 2.00 | 17 | 10.8 | 11.0 | 14.3 |
| 3.00 | 26 | 16.6 | 16.6 | 31.2 |
| 4.00 | 53 | 33.8 | 34.4 | 65.6 |
| 5.00 | 30 | 19.1 | 19.5 | 85.1 |
| 6.00 | 13 | 8.3 | 8.4 | 93.5 |
| 7.00 | 6 | 3.8 | 3.9 | 97.4 |
| 8.00 | 3 | 1.9 | 1.9 | 99.4 |
| 9.00 | 1 | 0.6 | 0.6 | 100.0 |
| 0.0 | 3 | 1.9 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 4.104 Mode 4.000 Median 4.047 Kurtosis 0.481

Std Dev 1.505 Skewness 0.400 Variance 2.264

Missing Observations 3

VARIABLE - OVERA~~LL~~ QUALITY OF ACCESSIBILITY-NOW

TABLE 24

| | Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) |
|---|---|---|---|---|
| Yes | 1.00 | 141 | 89.8 | 89.8 |
| No | 10.00 | 16 | 10.2 | 10.2 |
| | 0.0 | 0 | 0.0 | Missing |
| | Total | 157 | 100.0 | 100.0 |

VARIABLE - CITY WATER AVAILABILITY

TABLE 25

| | Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) |
|---|---|---|---|---|
| Yes | 1.00 | 106 | 67.5 | 69.3 |
| No | 10.00 | 47 | 29.9 | 30.7 |
| | 0.0 | 4 | 2.5 | Missing |
| | Total | 157 | 100.0 | 100.0 |

VARIABLE - CITY SEWAGE AVAILABILITY

TABLE 26

C. 2

| | Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) |
|---|---|---|---|---|
| Yes | 1.00 | 137 | 87.3 | 87.3 |
| No | 10.00 | 20 | 12.7 | 12.7 |
| | 0.0 | 0 | 0.0 | Missing |
| | Total | 157 | 100.0 | 100.0 |

VARIABLE - GAS AVAILABILITY

TABLE 27

| | Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) |
|---|---|---|---|---|
| Yes | 1.00 | 98 | 62.4 | 63.2 |
| No | 10.00 | 57 | 12.7 | 36.7 |
| | 0.0 | 2 | 1.3 | Missing |
| | Total | 157 | 100.0 | 100.0 |

VARIABLE - DID COMMUNITY HAVE ZONING THEN?

TABLE 28

restrictions but enjoy other city benefits. In such instances only minimum sewage treatment is required and the industries will install their own facilities. This is reflected by the lower percentage of sites selected having preexisting sewage treatment facilities.

Table 28, 29, and 30 reflect measurements of compatibility associated with the sites surveyed. Attributes which were measured include: Did the community have zoning at the time of the event? Was the site zoned for industry? and Was industry already in the immediate area? Industrial zoning affects site selection significantly (60 percent of the sites examined were located in areas zoned for industry). This is interesting considering Tennessee does not require counties to exercise zoning control and consequently industry is not restricted by public policy in site selection. County governments, however, can exercise quasi-zoning control by limiting cooperation in road construction and other services. The existence of other industries nearby the potential sites also appears to be a strong influence in the site selection process. This applies both in urban fringe and near CBD cases.

In lieu of recording each type of land use adjacent to the sites surveyed, an aggregate measure of land use compatibility (the overall rating of continuous land use compatibility) was included. Measurements varied from 1 = no problem with adjoining land use (e.g., situations with industry all around or open farm land or forest land all around) to 10 = significant compatibility problems (e.g., situations where the site was adjacent to a wealthy neighborhood, a hospital, or recreation area. Very few sites were objectionably located and most of those cases were in small communities where complainants would be few (Table 31).

| | Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) |
|---|---|---|---|---|
| Yes | 1.00 | 87 | 55.4 | 65.9 |
| No | 10.00 | 45 | 28.7 | 34.1 |
| | 0.0 | 25 | 15.9 | Missing |
| | Total | 157 | 100.0 | 100.0 |

VARIABLE - WAS IT ZONED FOR INDUSTRY?

TABLE 29

| | Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) |
|---|---|---|---|---|
| Yes | 1.00 | 110 | 70.1 | 71.4 |
| No | 10.00 | 44 | 28.0 | 28.6 |
| | 0.0 | 3 | 1.9 | Missing |
| | Total | 157 | 100.0 | 100.0 |

VARIABLE - WAS INDUSTRY ALREADY IN AREA?

TABLE 30

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 58 | 36.9 | 37.7 | 37.7 |
| 2.00 | 30 | 19.1 | 19.5 | 57.1 |
| 3.00 | 26 | 16.6 | 16.9 | 74.0 |
| 4.00 | 19 | 12.1 | 12.3 | 86.4 |
| 5.00 | 11 | 7.0 | 7.1 | 93.5 |
| 6.00 | 5 | 3.2 | 3.2 | 96.8 |
| 7.00 | 3 | 1.9 | 1.9 | 98.7 |
| 8.00 | 2 | 1.3 | 1.3 | 100.0 |
| 0.0 | 3 | 1.9 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 2.558 Mode 1.000 Median 2.133 Kurtosis 0.566

Std Dev 1.692 Skewness 1.061 Variance 2.863

Missing Observations 3

VARIABLE - OVERALL RATING OF CONTINGUOUS LAND USE COMPATABILITY

TABLE 31

Condition of neighborhood was included to measure the effect of value of housing on site selection processes. This was also considered a surrogate measure of family income and worker occupation types near the sites. Difficulty incurred in applying the measure to sites in rural or open land. As can be seen from Table 32, the distribution is platykurtic with some skewness toward low quality neighborhoods.

The number of community services near the site was assessed to determine if proximity to gas stations, restaurants, parks, golf courses, clubs, banks, and other commercial development affected industrial site selection. Table 33 indicates that 70 percent of the sites had at least two services nearby and 30 percent had four or more. Measuring this variable, however, presents problems when industries are locating near existing industrial development. In subsequent studies, it is believed that control should be introduced if industry presently exists in the vicinity of the site surveyed.

It was posited that designated industrial park space would be a strong variable in industrial site selection. Only 37 percent of the industry located in industrial parks (Table 34). However, many recent industries have located in industrial parks indicating a trend toward such locations.

Additional data concerning industrial park quality was collected but not included in the analysis because of the high percentage of missing observations (63.1 percent). Table 35, however, indicated the distribution of the data collected.

Finally, three additional variables were included in the analysis. These were: (1) Proximity of site to Knoxville; (2) Amount of other

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 2.00 | 3 | 1.9 | 2.0 | 2.0 |
| 3.00 | 22 | 14.0 | 14.7 | 16.7 |
| 4.00 | 26 | 16.6 | 17.3 | 34.0 |
| 5.00 | 35 | 22.3 | 23.3 | 57.3 |
| 6.00 | 26 | 16.6 | 17.3 | 74.7 |
| 7.00 | 17 | 10.8 | 11.3 | 86.0 |
| 8.00 | 17 | 10.8 | 11.3 | 97.3 |
| 9.00 | 4 | 2.5 | 2.7 | 100.0 |
| 0.0 | 7 | 4.5 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 5.320 Mode 5.000 Median 5.186 Kurtosis -0.771

Std Dev 1.712 Skewness 0.228 Variance 2.930

Missing Observations 7

VARIABLE - CONDITION OF NEIGHBORHOOD

TABLE 32

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 34 | 21.7 | 22.7 | 22.7 |
| 2.00 | 20 | 12.7 | 13.3 | 36.0 |
| 3.00 | 24 | 15.3 | 16.0 | 52.0 |
| 4.00 | 7 | 4.5 | 4.7 | 56.7 |
| 5.00 | 14 | 8.9 | 9.3 | 66.0 |
| 6.00 | 6 | 3.8 | 4.0 | 70.0 |
| 7.00 | 11 | 7.0 | 7.3 | 77.3 |
| 8.00 | 13 | 8.3 | 8.7 | 86.0 |
| 9.00 | 19 | 12.1 | 12.7 | 98.7 |
| 10.00 | 2 | 1.3 | 1.3 | 100.0 |
| 0.0 | 7 | 4.5 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 4.347 Mode 1.000 Median 3.375 Kurtosis -1.288

Std Dev 2.936 Skewness 0.414 Variance 8.617

Missing Observations 7

VARIABLE - DENSITY OF LAND USE

TABLE 33

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 18 | 11.5 | 12.2 | 12.2 |
| 2.00 | 8 | 5.1 | 5.4 | 17.6 |
| 3.00 | 8 | 5.1 | 5.4 | 23.0 |
| 4.00 | 7 | 4.5 | 4.7 | 27.7 |
| 5.00 | 11 | 7.0 | 7.4 | 35.1 |
| 6.00 | 11 | 7.0 | 7.4 | 42.6 |
| 7.00 | 15 | 9.6 | 10.1 | 52.7 |
| 8.00 | 21 | 13.4 | 14.2 | 66.9 |
| 9.00 | 22 | 14.0 | 14.9 | 81.8 |
| 10.00 | 27 | 17.2 | 18.2 | 100.0 |
| 0.0 | 9 | 5.7 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 6.405 Mode 10.000 Median 7.233 Kurtosis -1.066

Std Dev 3.079 Skewness -0.525 Variance 9.481

Missing Observations 9

VARIABLE - NEARBY COMMUNITY SERVICES

TABLE 34

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 58 | 36.9 | 37.2 | 37.2 |
| 10.00 | 98 | 62.4 | 62.8 | 100.0 |
| 0.0 | 1 | 0.6 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 6.654 Mode 10.000 Median 0.0 Kurtosis -1.719

Std Dev 4.364 Skewness -0.531 Variance 19.041

Missing Observations 1

VARIABLE - WAS THE SITE IN INDUSTRIAL PARK?

TABLE 35

industry located nearby; and (3) Was a suitable building already there? (Tables 36, 37, and 38).

Proximity to Knoxville was included to determine if orientation toward Knoxville had an impact on the process. Some effect is indicated (low values = orientation toward Knoxville) but a large percent of the sample came from the Knoxville vicinity. Because of this bias, this variable was eliminated from the factor analysis.

The existence of a suitable building at the site seems to have influenced the decision process to some extent (30 percent). Also the amount of industry nearby seems to have influenced location decisions.

## Results of the Factor Analysis

The SPSS factor analysis procedures were discussed in the preceding chapter and will not be repeated here. Table 39 presents the correlation coefficient matrix for the 27 variables used in the factor analysis. Correlation values greater than $\pm .50$ are considered to be significant. In general, the values associated with each pair of variables agree with theoretical expectations.

Eigen values associated with the initial factor matrix are found in Table 40. The eigen-values represent the proportion of the standardized total variance (27) accounted for by each factor. The SPSS factor analysis routine automatically stops extracting factors when the eigenvalue for a factor falls below one. This assures that only factors accounting for at least the average total variance (1/27) will be treated as significant. In this case seven factors were extracted accounting for 72 percent of the original variance.

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 8 | 5.1 | 13.8 | 13.8 |
| 2.00 | 9 | 5.7 | 15.5 | 29.3 |
| 3.00 | 11 | 7.0 | 19.0 | 48.3 |
| 4.00 | 14 | 8.9 | 24.1 | 72.4 |
| 5.00 | 9 | 5.7 | 15.5 | 87.9 |
| 6.00 | 4 | 2.5 | 6.9 | 94.8 |
| 7.00 | 3 | 1.9 | 5.2 | 100.0 |
| 0.0 | 99 | 63.1 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 3.534 Mode 4.000 Median 3.571 Kurtosis -0.681

Std Dev 1.667 Skewness 0.191 Variance 2.779

Missing Observations 99

VARIABLE - WHAT WAS THE QUALITY OF THE SITE?

TABLE 36

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 16 | 10.2 | 10.2 | 10.2 |
| 2.00 | 29 | 18.5 | 18.5 | 28.7 |
| 3.00 | 29 | 18.5 | 18.5 | 47.1 |
| 4.00 | 26 | 16.6 | 16.6 | 63.7 |
| 5.00 | 8 | 5.1 | 5.1 | 68.8 |
| 6.00 | 7 | 4.5 | 4.5 | 73.2 |
| 7.00 | 12 | 7.6 | 7.6 | 80.9 |
| 8.00 | 15 | 9.6 | 9.6 | 90.4 |
| 9.00 | 10 | 6.4 | 6.4 | 96.8 |
| 10.00 | 5 | 3.2 | 3.2 | 100.0 |
| 0.0 | 0 | 0.0 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 4.401 Mode 2.000 Median 3.673 Kurtosis -0.876

Std Dev 2.628 Skewness 0.594 Variance 6.908

Missing Observations 0

VARIABLE - PROXIMITY TO KNOXVILLE

TABLE 37

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 30 | 19.1 | 19.4 | 19.4 |
| 2.00 | 9 | 5.7 | 5.8 | 25.2 |
| 3.00 | 10 | 6.4 | 6.5 | 31.6 |
| 4.00 | 6 | 3.8 | 3.9 | 35.5 |
| 5.00 | 14 | 8.9 | 9.0 | 44.5 |
| 6.00 | 8 | 5.1 | 5.2 | 49.7 |
| 7.00 | 12 | 7.6 | 7.7 | 57.4 |
| 8.00 | 21 | 13.4 | 13.5 | 71.0 |
| 9.00 | 13 | 8.3 | 8.4 | 79.4 |
| 10.00 | 32 | 20.4 | 20.6 | 100.0 |
| 0.0 | 2 | 1.3 | Missing | 100.0 |
| Total | 157 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 5.865 Mode 10.000 Median 6.542 Kurtosis -1.439

Std Dev 3.365 Skewness -0.234 Variance 11.326

Missing Observations 2

VARIABLE - AMOUNT OF OTHER INDUSTRY LOCATED NEARBY

TABLE 38

| | Row | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Columns | | | | | | | | |
| Slope of land | 1 | 1.000 | -.247 | .519 | .132 | -.007 | -.126 | -.088 | -.130 | .055 |
| Drainage | 2 | -.247 | 1.000 | -.027 | .070 | .088 | -.093 | -.065 | .013 | .013 |
| Clearing-cover conditions | 3 | .519 | -.027 | 1.000 | .146 | .048 | -.143 | -.143 | -.141 | .038 |
| Distance to center of town | 4 | .132 | .070 | .146 | 1.000 | .206 | -.814 | -.529 | -.180 | .223 |
| Distance to nearest major thoroughfare | 5 | -.007 | .088 | .048 | .206 | 1.000 | -.223 | -.110 | -.218 | .345 |
| Density of land use in immediate vicinity | 6 | -.126 | -.093 | -.143 | -.814 | -.223 | 1.000 | .500 | .244 | -.214 |
| Rating of price of land | 7 | -.088 | -.065 | -.143 | -.529 | -.110 | .500 | 1.000 | -.047 | -.315 |
| Percent of urban area within 2-1/2 miles | 8 | -.130 | .013 | -.141 | -.180 | -.218 | .244 | -.047 | 1.000 | .169 |
| Distance to major highway | 9 | .055 | .013 | .038 | .223 | .345 | -.214 | -.315 | .169 | 1.000 |
| Distance to secondary road | 10 | .074 | -.033 | -.075 | .083 | -.208 | -.158 | -.248 | -.078 | -.157 |
| Distance to railway | 11 | .150 | -.114 | .158 | .082 | .074 | .028 | -.312 | -.023 | .055 |
| Distance to airport | 12 | -.054 | .138 | -.032 | .399 | .016 | -.413 | -.338 | .350 | .154 |
| Distance to waterway | 13 | .018 | .058 | .135 | .315 | -.011 | -.232 | -.256 | .222 | .121 |
| Distance to nearest Interstate | 14 | .049 | -.066 | -.031 | .390 | .188 | -.373 | -.426 | .275 | .702 |
| Overall quality of accessibility - then | 15 | .036 | .076 | .087 | .427 | .081 | -.363 | -.503 | .277 | .472 |
| City water availability | 16 | .350 | .053 | .203 | .401 | .070 | -.347 | -.370 | -.085 | .122 |
| Gas availability | 17 | .250 | .028 | .150 | .388 | .203 | -.299 | -.521 | .148 | .624 |
| City sewage availability | 18 | .184 | .088 | .140 | .493 | .143 | -.495 | -.647 | -.079 | .141 |
| Did community have zoning then? | 19 | -.001 | .084 | .031 | .225 | -.014 | -.162 | -.503 | .360 | .205 |
| Was it zoned for industry? | 20 | .113 | .034 | .128 | .351 | .060 | -.248 | -.638 | .149 | .248 |
| Was industry already in area? | 21 | .147 | .078 | .167 | .350 | .470 | -.223 | -.491 | .114 | .249 |
| Was a building already there? | 22 | .120 | -.073 | .138 | .372 | -.061 | -.449 | -.107 | -.240 | .105 |
| Rating of land use compatibility | 23 | -.070 | -.168 | -.013 | -.246 | -.247 | .298 | -.038 | .299 | -.040 |
| Nearby community services | 24 | -.225 | -.033 | -.261 | -.650 | -.093 | .637 | .608 | .063 | -.117 |
| Was the site in an industrial park? | 25 | -.038 | .072 | .015 | -.129 | -.037 | .201 | -.335 | .336 | -.081 |
| Proximity to Knoxville | 26 | .121 | .026 | .013 | .409 | .100 | -.405 | -.300 | .159 | .203 |
| Amount of other industry located nearby | 27 | -.137 | -.046 | -.227 | -.486 | -.093 | .434 | .696 | -.136 | -.205 |

CORRELATION MATRIX

TABLE 39

| | | Columns | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Row | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| Slope of land | 1 | .074 | .150 | -.054 | .018 | .049 | .036 | .350 | .250 | .184 |
| Drainage | 2 | -.033 | -.114 | .138 | .058 | -.066 | .076 | .053 | .028 | .088 |
| Clearing-cover conditions | 3 | -.075 | .158 | -.032 | .135 | -.031 | .087 | .203 | .150 | .140 |
| Distance to center of town | 4 | .083 | .082 | .399 | .315 | .390 | .427 | .401 | .388 | .493 |
| Distance to nearest major throughfare | 5 | -.208 | .074 | .016 | -.011 | .188 | .081 | .070 | .203 | .143 |
| Density of land use in immediate vicinity | 6 | -.158 | .028 | -.413 | -.232 | -.373 | -.363 | -.347 | -.299 | -.495 |
| Rating of price of land | 7 | -.248 | -.312 | -.338 | -.256 | -.426 | -.503 | -.370 | -.521 | -.647 |
| Percent of urban area within 2-1/2 miles | 8 | -.078 | -.023 | .350 | .222 | .275 | .277 | -.085 | .148 | -.079 |
| Distance to major highway | 9 | -.157 | .055 | .154 | .121 | .702 | .472 | .122 | .624 | .141 |
| Distance to secondary road | 10 | 1.000 | .045 | .124 | .081 | .075 | .119 | .022 | .046 | .289 |
| Distance to railway | 11 | .045 | 1.000 | -.144 | .188 | -.010 | .388 | .078 | .116 | .304 |
| Distance to airport | 12 | .124 | -.144 | 1.000 | .646 | .465 | .701 | .124 | .295 | .292 |
| Distance to waterway | 13 | .081 | .188 | .646 | 1.000 | .278 | .736 | -.052 | .231 | .207 |
| Distance to nearest interstate | 14 | .075 | -.010 | .465 | .278 | 1.000 | .599 | .175 | .710 | .264 |
| Overall quality of accessibility - then | 15 | .119 | .388 | .701 | .736 | .599 | 1.000 | .132 | .513 | .407 |
| City water availability | 16 | .022 | .078 | .124 | -.052 | .175 | .132 | 1.000 | .479 | .472 |
| Gas availability | 17 | .046 | .116 | .295 | .231 | .710 | .513 | .479 | 1.000 | .390 |
| City sewage availability | 18 | .289 | .304 | .292 | .207 | .264 | .407 | .472 | .390 | 1.000 |
| Did community have zoning then? | 19 | .246 | .003 | .434 | .220 | .355 | .376 | .243 | .404 | .525 |
| Was it zoned for industry? | 20 | .264 | .106 | .346 | .225 | .446 | .465 | .453 | .500 | .605 |
| Was industry already in area? | 21 | .089 | .324 | .178 | .243 | .311 | .392 | .272 | .414 | .444 |
| Was a building already there? | 22 | .020 | -.061 | .183 | .196 | .108 | .122 | .177 | .112 | .080 |
| Rating of land use compatibility | 23 | -.043 | .354 | -.066 | .089 | -.036 | .165 | -.180 | -.074 | -.090 |
| Nearby community services | 24 | -.109 | -.032 | -.351 | -.302 | -.210 | -.288 | -.441 | -.271 | -.494 |
| Was the site in an industrial park? | 25 | .179 | .107 | .143 | .009 | .047 | .141 | .151 | .156 | .365 |
| Proximity to Knoxville | 26 | .180 | -.040 | .752 | .544 | .472 | .612 | .180 | .329 | .251 |
| Amount of other industry located nearby | 27 | -.195 | -.353 | -.363 | -.358 | -.353 | -.527 | -.352 | -.449 | -.651 |

TABLE 39 - Continued

| | | Columns | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Row | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| Slope of land | 1 | -.001 | .113 | .147 | .120 | -.070 | -.225 | -.038 | .121 | -.137 |
| Drainage | 2 | .084 | .034 | .078 | -.073 | -..68 | -.033 | .072 | .026 | -.045 |
| Clearing-cover conditions | 3 | .031 | .128 | .167 | .138 | -.013 | -.261 | .015 | .013 | -.227 |
| Distance to center of town | 4 | .225 | .351 | .350 | .372 | -.246 | -.650 | -.129 | .409 | -.486 |
| Distance to nearest major throughfare | 5 | -.014 | .060 | .147 | -.061 | -.247 | -.093 | -.037 | .100 | -.093 |
| Density of land use in immediate vicinity | 6 | -.162 | -.248 | -.223 | -.449 | .298 | .637 | .201 | -.405 | .434 |
| Rating of price of land | 7 | -.503 | -.638 | -.491 | -.107 | -.038 | .608 | -.335 | -.300 | .696 |
| Percent of urban area within 2-1/2 miles | 8 | .360 | .149 | .114 | -.240 | .299 | .063 | .336 | .159 | -.136 |
| Distance to major highway | 9 | .205 | .248 | .249 | .105 | -.040 | -.117 | -.081 | .203 | -.205 |
| Distance to secondary road | 10 | .246 | .264 | .089 | .020 | -.043 | -.109 | .179 | .180 | -.195 |
| Distance to railway | 11 | .003 | .106 | .324 | -.061 | .354 | -.032 | .107 | -.040 | -.353 |
| Distance to airport | 12 | .434 | .346 | .178 | .183 | -.066 | -.351 | .143 | .752 | -.363 |
| Distance to waterway | 13 | .220 | .225 | .243 | .196 | .089 | -.302 | .009 | .544 | -.358 |
| Distance to nearest interstate | 14 | .355 | .446 | .311 | .108 | -.036 | -.210 | .047 | .472 | -.353 |
| Overall quality of accessibility - then | 15 | .376 | .465 | .392 | .122 | .165 | -.288 | .141 | .612 | -.527 |
| City water availability | 16 | .243 | .453 | .272 | .117 | -.180 | -.441 | .151 | .180 | -.352 |
| Gas availability | 17 | .404 | .500 | .414 | .112 | -.074 | -.271 | .156 | .329 | -.449 |
| City sewage availability | 18 | .525 | .605 | .444 | .080 | -.090 | -.494 | .365 | .251 | -.651 |
| Did community have zoning then? | 19 | 1.000 | .849 | .437 | -.038 | .038 | -.293 | .532 | .277 | -.471 |
| Was it zoned for industry? | 20 | .849 | 1.000 | .580 | .001 | .106 | -.366 | .508 | .251 | -.606 |
| Was industry already in area? | 21 | .437 | .580 | 1.000 | -.080 | .111 | -.364 | .373 | .244 | -.737 |
| Was a building already there? | 22 | -.038 | .001 | -.080 | 1.000 | -.264 | -.265 | -.437 | .162 | .045 |
| Rating of land use compatibility | 23 | .038 | .106 | .111 | -.264 | 1.000 | .232 | .193 | -.115 | -.200 |
| Nearby community services | 24 | -.293 | -.366 | -.364 | -.265 | .232 | 1.000 | -.076 | -.368 | .563 |
| Was the site in an industrial park? | 25 | .532 | .508 | .373 | -.437 | .193 | -.076 | 1.000 | -.011 | -.433 |
| Proximity to Knoxville | 26 | .277 | .251 | .244 | .162 | -.115 | -.368 | -.011 | 1.000 | -.319 |
| Amount of other industry located nearby | 27 | -.471 | -.606 | -.737 | .045 | -.200 | .563 | -.433 | -.319 | 1.000 |

TABLE 39 - Continued

| Factor | Eigen Value | Pct. of Var. | Cum. Pct. |
|---|---|---|---|
| 1 | 7.79292 | 28.9 | 28.9 |
| 2 | 3.02117 | 11.2 | 40.1 |
| 3 | 2.02117 | 9.2 | 49.3 |
| 4 | 1.87910 | 7.0 | 56.2 |
| 5 | 1.75885 | 6.5 | 62.7 |
| 6 | 1.39755 | 5.2 | 67.9 |
| 7 | 1.17964 | 4.4 | 72.3 |
| 8 | 0.94247 | 3.5 | 75.8 |
| 9 | 0.84998 | 3.1 | 78.9 |
| 10 | 0.75369 | 2.8 | 81.7 |
| 11 | 0.67677 | 2.5 | 84.2 |
| 12 | 0.56666 | 2.1 | 86.3 |
| 13 | 0.53530 | 2.0 | 88.3 |
| 14 | 0.42438 | 1.6 | 89.9 |
| 15 | 0.37718 | 1.4 | 91.3 |
| 16 | 0.35815 | 1.3 | 92.6 |
| 17 | 0.33950 | 1.3 | 93.8 |
| 18 | 0.32075 | 1.2 | 95.0 |
| 19 | 0.28415 | 1.1 | 96.1 |
| 20 | 0.23591 | 0.9 | 97.0 |
| 21 | 0.18443 | 0.7 | 97.6 |
| 22 | 0.17080 | 0.6 | 98.3 |
| 23 | 0.15223 | 0.6 | 98.8 |
| 24 | 0.12058 | 0.4 | 99.3 |
| 25 | 0.10901 | 0.4 | 99.7 |
| 26 | 0.07168 | 0.3 | 100.0 |
| 27 | 0.01322 | 0.0 | 100.0 |

EIGEN VALUES

TABLE 40

Some explanation of the "loadings" or "scores" found in the factor matrix is necessary before discussing the results of this analysis. Scores found in the factor matrix are evaluated similar to correlation or regression coefficients. Values may range from +1 to -1. The greater the absolute value of the score, the greater the relationship between the factor and the variable. The level at which factor loadings may be considered as significant is open to question. Most statisticians suggest that loadings greater than $|.50|$ should be considered significant. Ideally, only a small number of variables should load significantly on more than one column in the matrix. Variables loading on more than one factor complicate the interpretation of factors. Columns with a high number of significant loadings should have at least as many near zero loadings as the number of factors derived.[4]

Attention is directed to a comparison between the unrotated factor matrix (Table 41) and the rotated factor matrix (Table 42). Note that rotation of the axis simplifies interpretation of the factors. In interpreting the rotated matrix, the original 27 variables have been collapsed to seven factors accounting for 72 percent of the original variance. Approximately 20 variables can be identified as significant. The following list summarizes the variables which load significantly on each factor.

---

[4]Nie and others, p. 223.

| | Factors | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Slope of land | -.2067 | .2232 | .4081 | -.2240 | .3973 | .6317 | -.0849 |
| Drainage | -.0736 | .0004 | -.0584 | .1243 | -.2121 | -.1658 | -.2396 |
| Clearing-cover conditions | -.1970 | .1483 | .3035 | -.0923 | .3060 | .2306 | -.1781 |
| Distance to center of town | -.6782 | .4880 | .0749 | .1088 | -.0269 | -.1692 | .0318 |
| Distance to nearest major throughfare | -.1730 | .2049 | .0288 | -.3079 | -.1480 | -.2576 | -.3660 |
| Density of land use in immediate vicinity | .6229 | -.6059 | -.0571 | -.1640 | .0894 | .1659 | -.0844 |
| Rating of price of land | .7796 | .0663 | -.2166 | -.0212 | .0331 | .1725 | -.1362 |
| Percent of urban area within 2-1/2 miles | -.1510 | -.5074 | -.3812 | -.0212 | -.0148 | .1727 | -.0253 |
| Distance to major highway | -.4427 | .0672 | -.2789 | -.6941 | -.1252 | -.0814 | .0108 |
| Distance to secondary road | -.2102 | -.0816 | .1052 | .2768 | -.0355 | .0772 | .2752 |
| Distance to railway | -.2260 | -.2168 | .2428 | -.1532 | .5634 | -.3284 | .0710 |
| Distance to airport | -.6374 | .0250 | -.5857 | .3787 | -.0210 | .1872 | -.1563 |
| Distance to waterway | -.5026 | -.0003 | -.4337 | .2364 | .3990 | .0001 | -.1052 |
| Distance to nearest Interstate | -.6462 | .0167 | -.3867 | -.4301 | -.1635 | .0667 | .1739 |
| Overall quality of accessibility-then | -.7644 | -.1117 | -.4355 | -.0424 | .3435 | -.1096 | .0075 |
| City water availability | -.4629 | .1492 | .3647 | -.0729 | -.1296 | .1805 | -.0520 |
| Gas availability | -.6793 | .0012 | -.0393 | -.4660 | -.1118 | .1364 | .0283 |
| City sewage availability | -.7034 | -.0302 | .3539 | .1357 | -.0660 | -.1021 | .0363 |
| Did community have zoning then? | -.6303 | -.4140 | .0404 | .1291 | -.3171 | .1801 | .1013 |
| Was it zoned for industry? | -.7458 | -.3441 | .2116 | .0187 | -.2270 | .1215 | .1477 |
| Was industry already in area? | -.6126 | -.2440 | .2245 | -.0833 | .0712 | -.1265 | -.1383 |
| Was a building already there? | -.1761 | .5503 | -.0764 | .0748 | .0769 | .0734 | .2634 |
| Rating of land use compatibility | .0372 | -.5217 | -.0405 | -.0533 | .3853 | -.1041 | .1835 |
| Nearby community services | .6336 | -.3111 | -.2232 | -.2228 | .0101 | -.0049 | .0809 |
| Was the site in an industrial park? | -.2980 | -.6928 | .2429 | .1432 | -.1896 | .0685 | -.1857 |
| Proximity to Knoxville | -.5761 | .1559 | -.4078 | .1766 | .0794 | .1646 | -.1097 |
| Amount of other industry located nearby | .7873 | .2211 | -.2532 | -.0800 | -.1499 | .1823 | .0858 |

UNROTATED FACTOR MATRIX

TABLE 41

| | Factors | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Slope of land | .0680 | -.0152 | -.0857 | .0798 | .9102 | -.0036 | .1625 |
| Drainage | .1066 | .0854 | -.0042 | -.0774 | -.1740 | -.1210 | -.2908 |
| Clearing-cover conditions | .1004 | .0302 | -.0999 | -.0263 | .5481 | .1176 | -.0644 |
| Distance to center of town | .3789 | .2791 | -.6820 | .1617 | .0756 | .0295 | -.1634 |
| Distance to nearest major throughfare | .0263 | -.0487 | -.1359 | .2455 | .0308 | .0107 | -.5540 |
| Density of land use in immediate vicinity | -.3218 | -.2540 | .7884 | -.1284 | -.0314 | .0584 | .1319 |
| Rating of price of land | -.7079 | -.1708 | .2698 | -.2332 | -.0151 | -.2251 | .0242 |
| Percent of urban area within 2-1/2 miles | .1087 | .3475 | .5006 | .1897 | -.1362 | -.0204 | .1361 |
| Distance to major highway | .0515 | .0920 | -.0500 | .8469 | .0081 | .0742 | -.2148 |
| Distance to secondary road | .3127 | .0697 | -.1052 | -.1105 | -.0575 | -.0197 | .3031 |
| Distance to railway | .1630 | -.0041 | .0091 | .0179 | .1473 | .7497 | -.0069 |
| Distance to airport | .2474 | .9025 | -.0835 | .1036 | -.0909 | -.2272 | .0002 |
| Distance to waterway | .0818 | .7715 | -.0879 | .0411 | .0383 | .2319 | .0167 |
| Distance to nearest Interstate | .2388 | .3335 | -.0991 | .7939 | -.0546 | -.0398 | .0296 |
| Overall quality of accessibility-then | .2737 | .7354 | -.0776 | .3938 | -.0132 | .3758 | -.0041 |
| City water availability | .4618 | -.0474 | -.2300 | .1449 | .3410 | -.1211 | -.0809 |
| Gas availability | .3970 | .1632 | -.0772 | .6853 | .2146 | .0021 | -.0782 |
| City sewage availability | .7317 | .1081 | -.2707 | .0559 | .1039 | .1287 | -.0680 |
| Did community have zoning then? | .7436 | .2299 | .1765 | .2003 | -.0742 | -.1626 | .1452 |
| Was it zoned for industry? | .8335 | .1382 | .0511 | .2711 | .0455 | -.0162 | .1244 |
| Was industry already in area? | .5867 | .1488 | .0333 | .1699 | .1395 | .2804 | -.1951 |
| Was a building already there? | -.1042 | .1399 | -.5801 | .0959 | .0948 | -.0838 | .1895 |
| Rating of land use compatibility | .0298 | .0474 | .3902 | -.0099 | -.0700 | .4954 | .2554 |
| Nearby community services | -.4895 | -.2574 | .4806 | .0193 | -.2198 | .0327 | .1330 |
| Was the site in an industrial park? | .6540 | .0257 | .5290 | -.1044 | -.0253 | .0079 | -.0599 |
| Proxomity to Knoxville | .1682 | .6957 | -.1905 | .1818 | .0692 | -.1110 | -.0170 |
| Amount of other industry located nearby | -.7324 | -.2781 | .0938 | -.0883 | -.1265 | -.3664 | .1475 |

VARIMAX ROTATED FACTOR MATRIX

TABLE 42

FACTOR I[5]

ZONED INDUSTRY
ZONING PRESENT
AMOUNT OF OTHER INDUSTRY LOCATED NEARBY
SEWAGE AVAILABLE
PRICE OF LAND
SITE IN INDUSTRIAL PARK
(INDUSTRY IN AREA)

FACTOR II

DISTANCE TO AIRPORT
DISTANCE TO WATERWAY
OVERALL QUALITY OF ACCESSIBILITY-THEN
PROXIMITY TO KNOXVILLE

FACTOR III

DENSITY OF LAND USE
DISTANCE TO CENTER OF TOWN
BUILDING PRESENT
(SITE IN INDUSTRIAL PARK)
(PERCENT OF URBAN AREA WITHIN TWO AND A HALF MILES)

FACTOR IV

DISTANCE TO MAJOR HIGHWAY
DISTANCE TO NEAREST INTERSTATE
GAS AVAILABILITY

FACTOR V

SLOPE OF LAND
(CLEARING-COVER CONDITIONS)

FACTOR VI

DISTANCE TO RAILWAY
(LAND USE COMPATIBILITY)

FACTOR VII

(DISTANCE TO NEAREST MAJOR THOROUGHFARE)

Several observations regarding the results of the factor analysis should be noted. Firstly, the variables did not group as previously conceived in Chapter II. This suggests that an alternate grouping of

[5]Variables are listed from highest factor score to lowest. Parentheses indicate variables with questionable significant loadings.

variables to form indexes should be considered. This is not particularly disturbing since the original grouping was based upon a literature search and not upon quantitative analysis.

Secondly, the first three factors account for nearly half of the original variance in the data (Table 40). These factors, therefore, may be sufficient to capture the industrial land conversion process provided appropriate weights can be found to reflect varying locational preferences of specific industries. This would reduce the number of variables to be measured to approximately 13.

Thirdly, a designated or zoned place for industry with some industry already nearby, appears to be the most important consideration in the site selection process. This is statistically verified only for the 16-county metropolitan region and such an observation is consistent with empirical studies noted in Chapter II.

Finally, the remaining factors, although identified as statistically distinct, have a degree of communality in that each relates to some aspect of accessibility to the site. This suggests that a combined index of accessibility should be considered.

# V. EMPIRICAL ANALYSIS OF SINGLE-FAMILY RESIDENTIAL LOCATION EVENTS

This section discusses results of the analysis of residential land use development in the Knoxville metropolitan region. Only single-family developments were examined in the study and developments on land parcels smaller than 10 acres were not considered. A total of 33 variables are considered in the analysis.

## Descriptive Statistics

Utilizing NASA and TVA aerial photography of urban centers within the Knoxville metropolitan region, 50 residential development events occurring since 1966 were selected for detailed analysis. Obviously this represents a small sample; however, such a sample was considered adequate for inferential purposes.

Measurements for 33 variables were determined for each residential location event utilizing the aerial photography and topographic base maps. In all 1650 bits of data were collected for analysis. The selection of variables to be utilized was based upon a literature review and preliminary analysis similar to the industrial land use analysis.

Three types of variables were included in the analysis: accessibility variables, compatibility variables, and site suitability variables:

### Accessibility variables

ACC 1 — Distance of nearest residential area

ACC 2 — Distance to commercial area

ACC 3 — Distance to industrial area

ACC 4 — Distance to institutional use (other than school)

ACC 5 — Distance to recreation area

ACC 6 — Distance to nearest school

ACC 7 — Distance to transportation barrier

ACC 8 — Distance to greenbelt or water body

ACC 9 — Distance to limited access highway

ACC 10 — Distance to major arterial highway

ACC 11 — Distance to collector highway

<u>Compatibility variables</u>

COMP 1 — Adjacent to residential area

COMP 2 — Adjacent to commercial area

COMP 3 — Adjacent to industrial area

COMP 4 — Adjacent to institutional facility

COMP 5 — Adjacent to recreational facility

COMP 6 — Adjacent to school

COMP 7 — Adjacent to transportation barrier

COMP 8 — Adjacent to greenbelt or water body

COMP 9 — Adjacent to arterial highway

COMP 10 — Adjacent to collector highway

<u>Site suitability variables</u>

Suit. 1 — Size of tract

Suit. 2 — Slope

Suit. 3 — Land cover

Suit. 4 — Drainage

Suit. 5 — Density of adjacent development

Suit. 6 — Obnoxious adjacent development rating

Suit. 7 — Scenic vista rating

Suit. 8 — City water

Suit. 9 — City sewerage

Suit. 10 — Fire protection

Suit. 11 — Trash collection

Suit. 12 — Gas service

Accessibility variables were scored values from 1 to 10, with a value of 1 considered adjacent and a value 10 representing 2 or more miles. Compatibility variables were evaluated from 0 to 4 reflecting the number of sides the land parcel bordered specific land uses. Site suitability variables were measured as follows: Size of tract was evaluated from 1 = 10 acres to 10 = 100 or more acres; Slope of land ranged from 1 = flat to 10 = 20% or greater slope; Drainage qualities, Density of Adjacent Development, Obnoxious Adjacent Development Rating, and Scenic Vista Rating were scored from 0 to 4. Municipal services (i.e., water, sewer, fire, trash, and gas) were scored yes = 1, no = 0 (see Appendix A).

## Description of Variables

The following tables provide a statistical summary of the measurements obtained for the 33 variables considered. Although the tables are easily interpreted, specific comments concerning each group of variables are summarized below:

Comments on accessibility variables

1. Most of the residential developments (86 percent) were within a half mile of existing residential development (Table 43).
2. The data indicate recent residential developments prefer to be 1/2 to 1 mile from commercial facilities (Table 44) and much farther away (1-1/2 to 2 or more miles) from industrial development (Table 45).
3. Eighty-six percent of the developments studied were within one mile of an institutional or a municipal facility (other than a school). In most cases this was a church. This would be expected, however, and probably does not reflect locational preference (Table 46).
4. Some preference to be near a recreational facility is indicated by the data but not significantly (Table 47).
5. Proximity to a school was clearly indicated as an important variable (Table 48).
6. Proximity to a transportation barrier such as a limited access highway, railroad, or power transmission line is difficult to interpret based on the distribution of the data. The factor analysis, however, indicated a negative influence on development (Table 49).
7. Forty-nine out of 50 observations were adjacent to greenbelt areas (forest, farms, water bodies, etc.). Its importance is intuitively obvious, however, and because of so little variance (0.08) it was eliminated from the factor analysis for statistical purposes (Table 50).

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 34 | 68.0 | 68.0 | 68.0 |
| 2.00 | 9 | 18.0 | 18.0 | 86.0 |
| 3.00 | 6 | 12.0 | 12.0 | 98.0 |
| 10.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.600 Mode 1.000 Median 0.0 Kurtosis 24.161

Std Dev 1.400 Skewness 4.529 Variance 1.959

Missing Observations 0

VARIABLE — DISTANCE OF NEAREST RESIDENTIAL AREA

TABLE 43

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj·Freq· (Percent) |
|---|---|---|---|---|
| 1.00 | 1 | 2.0 | 2.0 | 2.0 |
| 2.00 | 8 | 16.0 | 16.0 | 18.0 |
| 3.00 | 12 | 24.0 | 24.0 | 42.0 |
| 4.00 | 14 | 28.0 | 28.0 | 70.0 |
| 5.00 | 6 | 12.0 | 12.0 | 82.0 |
| 6.00 | 3 | 6.0 | 6.0 | 88.0 |
| 7.00 | 1 | 2.0 | 2.0 | 90.0 |
| 8.00 | 3 | 6.0 | 6.0 | 96.0 |
| 9.00 | 2 | 4.0 | 4.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 4.120 Mode 4.000 Median 3.786 Kurtosis 0.499

Std Dev 1.902 Skewness 0.995 Variance 3.618

Missing Observations 0

VARIABLE — DISTANCE TO COMMERCIAL AREA

TABLE 44

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 4 | 8.0 | 8.0 | 8.0 |
| 2.00 | 3 | 6.0 | 6.0 | 14.0 |
| 3.00 | 6 | 12.0 | 12.0 | 26.0 |
| 4.00 | 4 | 8.0 | 8.0 | 34.0 |
| 5.00 | 5 | 10.0 | 10.0 | 44.0 |
| 6.00 | 5 | 10.0 | 10.0 | 54.0 |
| 7.00 | 7 | 14.0 | 14.0 | 68.0 |
| 8.00 | 2 | 4.0 | 4.0 | 72.0 |
| 9.00 | 9 | 18.0 | 18.0 | 90.0 |
| 10.00 | 5 | 10.0 | 10.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 5.900 Mode 9.000 Median 6.100 Kurtosis -1.182

Std Dev 2.852 Skewness -0.165 Variance 8.133

Missing Observations 0

VARIABLE — DISTANCE TO INDUSTRIAL AREA

TABLE 45

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj·Freq· (Percent) |
|---|---|---|---|---|
| 1.00 | 6 | 12.0 | 12.0 | 12.0 |
| 2.00 | 15 | 30.0 | 30.0 | 42.0 |
| 3.00 | 11 | 22.0 | 22.0 | 64.0 |
| 4.00 | 6 | 12.0 | 12.0 | 76.0 |
| 5.00 | 5 | 10.0 | 10.0 | 86.0 |
| 6.00 | 2 | 4.0 | 4.0 | 90.0 |
| 7.00 | 3 | 6.0 | 6.0 | 96.0 |
| 9.00 | 1 | 2.0 | 2.0 | 98.0 |
| 10.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 3.400 Mode 2.000 Median 2.864 Kurtosis 1.353

Std Dev 2.060 Skewness 1.262 Variance 4.245

Missing Observations 0

VARIABLE — DISTANCE TO INSTITUTIONAL USE (OTHER THAN SCHOOL)

TABLE 46

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 8 | 16.0 | 16.0 | 16.0 |
| 2.00 | 8 | 16.0 | 16.0 | 32.0 |
| 3.00 | 5 | 10.0 | 10.0 | 42.0 |
| 4.00 | 9 | 18.0 | 18.0 | 60.0 |
| 5.00 | 5 | 10.0 | 10.0 | 70.0 |
| 6.00 | 3 | 6.0 | 6.0 | 76.0 |
| 7.00 | 1 | 2.0 | 2.0 | 78.0 |
| 8.00 | 7 | 14.0 | 14.0 | 92.0 |
| 9.00 | 2 | 4.0 | 4.0 | 96.0 |
| 10.00 | 2 | 4.0 | 4.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 4.380 Mode 4.000 Median 3.944 Kurtosis -0.900

Std Dev 2.717 Skewness 0.499 Variance 7.383

Missing Observations 0

VARIABLE — DISTANCE TO RECREATION AREA

TABLE 47

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 4 | 8.0 | 8.0 | 8.0 |
| 2.00 | 10 | 20.0 | 20.0 | 28.0 |
| 3.00 | 5 | 10.0 | 10.0 | 38.0 |
| 4.00 | 6 | 12.0 | 12.0 | 50.0 |
| 5.00 | 7 | 14.0 | 14.0 | 64.0 |
| 6.00 | 7 | 14.0 | 14.0 | 78.0 |
| 7.00 | 3 | 6.0 | 6.0 | 84.0 |
| 8.00 | 3 | 6.0 | 6.0 | 90.0 |
| 9.00 | 4 | 8.0 | 8.0 | 98.0 |
| 10.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 4.620 Mode 2.000 Median 4.500 Kurtosis -0.880

Std Dev 2.506 Skewness 0.360 Variance 6.281

Missing Observations 0

VARIABLE — DISTANCE TO NEAREST SCHOOL

TABLE 48

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 5 | 10.0 | 10.0 | 10.0 |
| 2.00 | 12 | 24.0 | 24.0 | 34.0 |
| 3.00 | 5 | 10.0 | 10.0 | 44.0 |
| 4.00 | 2 | 4.0 | 4.0 | 48.0 |
| 5.00 | 4 | 8.0 | 8.0 | 56.0 |
| 6.00 | 4 | 8.0 | 8.0 | 64.0 |
| 7.00 | 1 | 2.0 | 2.0 | 66.0 |
| 10.00 | 17 | 34.0 | 34.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 5.460 Mode 10.000 Median 4.750 Kurtosis -1.610

Std Dev 3.593 Skewness 0.255 Variance 12.907

Missing Observations 0

VARIABLE — DISTANCE TO TRANSPORTATION BARRIER

TABLE 49

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 49 | 98.0 | 98.0 | 98.0 |
| 3.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.040 Mode 1.000 Median 0.0 Kurtosis 45.020

Std Dev 0.283 Skewness 6.857 Variance 0.080

Missing Observations 0

VARIABLE — DISTANCE TO GREENBELT OR WATER BODY

TABLE 50

8. Distance to a limited access highway has little effect on residential site selection at least for the study sample (Table 51).

9. Nearness or adjacency to a major urban artery highway is clearly important (Table 52). Almost all sites examined (88 percent) were adjacent to a collector highway (Table 53).

Comments concerning compatibility variables

1. Seventy-eight percent of the sample developments bordered existing residential development at least on one side (Table 54).

2. Adjacency to commercial areas, industrial areas, institutional uses, recreational areas, and schools has a low frequency of occurrence and was eliminated from the initial factor analysis (Tables 55, 56, 57, 58, and 59).

3. Adjacency to a transportation barrier appeared to be important in the sample possibly because transmission corridors were included (Table 60).

4. The importance of being adjacent to a greenbelt or water body is indicated by the fact that 96 percent of the developments examined were bordered by a greenbelt on one or more sides (Table 61). This is expected as cities expand into surrounding agricultural land.

5. Note that only 32 percent of the sample sites were adjacent to major arterial highways (Table 62) while 92 percent were adjacent to collector highways (Table 63).

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 1 | 2.0 | 2.0 | 2.0 |
| 3.00 | 1 | 2.0 | 2.0 | 4.0 |
| 4.00 | 1 | 2.0 | 2.0 | 6.0 |
| 5.00 | 3 | 6.0 | 6.0 | 12.0 |
| 6.00 | 9 | 18.0 | 18.0 | 30.0 |
| 8.00 | 1 | 2.0 | 2.0 | 32.0 |
| 9.00 | 2 | 4.0 | 4.0 | 36.0 |
| 10.00 | 32 | 64.0 | 64.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 8.460 Mode 10.000 Median 0.0 Kurtosis 0.585

Std Dev 2.358 Skewness -1.270 Variance 5.560

Missing Observations 0

VARIABLE — DISTANCE TO LIMITED ACCESS HIGHWAY

TABLE 51

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 15 | 30.0 | 30.0 | 30.0 |
| 2.00 | 7 | 14.0 | 14.0 | 44.0 |
| 3.00 | 6 | 12.0 | 12.0 | 56.0 |
| 4.00 | 7 | 14.0 | 14.0 | 70.0 |
| 5.00 | 4 | 8.0 | 8.0 | 78.0 |
| 6.00 | 2 | 4.0 | 4.0 | 82.0 |
| 7.00 | 2 | 4.0 | 4.0 | 86.0 |
| 8.00 | 1 | 2.0 | 2.0 | 88.0 |
| 9.00 | 2 | 4.0 | 4.0 | 92.0 |
| 10.00 | 4 | 8.0 | 8.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 3.740 Mode 1.000 Median 3.000 Kurtosis -0.203

Std Dev 2.877 Skewness 0.954 Variance 8.278

Missing Observations 0

VARIABLE — DISTANCE TO MAJOR ARTERIAL HIGHWAY

TABLE 52

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 44 | 88.0 | 88.0 | 88.0 |
| 2.00 | 5 | 10.0 | 10.0 | 98.0 |
| 3.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.140 Mode 1.000 Median 0.0 Kurtosis 8.443

Std Dev 0.405 Skewness 2.956 Variance 0.164

Missing Observations 0

VARIABLE — DISTANCE TO COLLECTOR HIGHWAY

TABLE 53

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 11 | 22.0 | 22.0 | 22.0 |
| 1.00 | 22 | 44.0 | 44.0 | 66.0 |
| 2.00 | 14 | 28.0 | 28.0 | 94.0 |
| 3.00 | 3 | 6.0 | 6.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.180 Mode 1.000 Median 1.136 Kurtosis -0.580

Std Dev 0.850 Skewness 0.255 Variance 0.722

Missing Observations 0

VARIABLE — ADJACENT TO RESIDENTIAL AREA

TABLE 54

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 47 | 94.0 | 94.0 | 94.0 |
| 1.00 | 2 | 4.0 | 4.0 | 98.0 |
| 2.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.080 Mode 0.0 Median 0.0 Kurtosis 20.284

Std Dev 0.340 Skewness 4.498 Variance 0.116

Missing Observations 0

VARIABLE — ADJACENT TO COMMERCIAL AREA

TABLE 55

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 44 | 88.0 | 88.0 | 88.0 |
| 1.00 | 6 | 12.0 | 12.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.120 Mode 0.0 Median 0.0 Kurtosis 3.470

Std Dev 0.328 Skewness 2.339 Variance 0.108

Missing Observations 0

VARIABLE — ADJACENT TO INDUSTRIAL AREA

TABLE 56

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 46 | 92.0 | 92.0 | 92.0 |
| 1.00 | 4 | 8.0 | 8.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.080 Mode 0.0 Median 0.0 Kurtosis 7.587

Std Dev 0.274 Skewness 3.096 Variance 0.075

Missing Observations 0

VARIABLE — ADJACENT TO INSTITUTIONAL FACILITY

TABLE 57

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 41 | 82.0 | 82.0 | 82.0 |
| 1.00 | 8 | 16.0 | 16.0 | 98.0 |
| 2.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.200 Mode 0.0 Median 0.0 Kurtosis 3.920

Std Dev 0.452 Skewness 2.147 Variance 0.204

Missing Observations 0

VARIABLE — ADJACENT TO RECREATIONAL FACILITY

TABLE 58

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 45 | 90.0 | 90.0 | 90.0 |
| 1.00 | 4 | 8.0 | 8.0 | 98.0 |
| 2.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.120 Mode 0.0 Median 0.0 Kurtosis 11.057

Std Dev 0.385 Skewness 3.345 Variance 0.149

Missing Observations 0

VARIABLE — ADJACENT TO SCHOOL

TABLE 59

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 39 | 78.0 | 78.0 | 78.0 |
| 1.00 | 10 | 20.0 | 20.0 | 98.0 |
| 4.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.280 Mode 0.0 Median 0.0 Kurtosis 16.940

Std Dev 0.671 Skewness 3.704 Variance 0.451

Missing Observations 0

VARIABLE — ADJACENT TO TRANSPORTATION BARRIER

TABLE 60

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 2 | 4.0 | 4.0 | 4.0 |
| 1.00 | 2 | 4.0 | 4.0 | 8.0 |
| 2.00 | 14 | 28.0 | 28.0 | 36.0 |
| 3.00 | 21 | 42.0 | 42.0 | 78.0 |
| 4.00 | 11 | 22.0 | 22.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 2.740 Mode 3.000 Median 2.833 Kurtosis 0.596

Std Dev 0.986 Skewness -0.753 Variance 0.972

Missing Observations 0

VARIABLE — ADJACENT TO GREENBELT OR WATER BODY

TABLE 61

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 34 | 68.0 | 68.0 | 68.0 |
| 1.00 | 14 | 28.0 | 28.0 | 96.0 |
| 2.00 | 1 | 2.0 | 2.0 | 98.0 |
| 3.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.380 Mode 0.0 Median 0.0 Kurtosis 4.257

Std Dev 0.635 Skewness 1.906 Variance 0.404

Missing Observations 0

VARIABLE — ADJACENT TO ARTERIAL HIGHWAY

TABLE 62

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 9 | 18.0 | 18.0 | 18.0 |
| 1.00 | 32 | 64.0 | 64.0 | 82.0 |
| 2.00 | 9 | 18.0 | 18.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.000 Mode 1.000 Median 1.000 Kurtosis -0.222

Std Dev 0.606 Skewness 0.0 Variance 0.367

Missing Observations 0

VARIABLE — ADJACENT TO COLLECTOR HIGHWAY

TABLE 63

Comments on the site suitability variables

1. Most residential developments studied (in the Knoxville Metropolitan area) occurred on land parcels between 20 and 70 acres in size (Table 64).

2. The following physical characteristics were common to most sites: flat topography (<10% slope); little or no vegetation cover; and well drained surfaces (Tables 65, 66, and 67).

3. In most cases (96%) the development sites were open on 2 or more sides, and free of other urban development (Table 68).

4. Nearly half (46%) the observations had at least one side bordering a lower quality land use type (Table 69). This was often a residential development with smaller dwelling units.

5. Very few residential developments were located on parcels with outstanding vista ratings (scores of 3 or 4) (Table 70).

6. Municipal water supply existed at each residential development site indicating its importance to development (Table 71); however, because of the lack of statistical variance, the variable was eliminated from the factor analysis. Other municipal services (fire protection and trash collection) seem to have been less important to development (Tables 73 and 74) while the occurrence of municipal sewerage and gas service was important but did not appear to be quite as essential for development (Tables 72 and 75).

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 6 | 12.0 | 12.0 | 12.0 |
| 2.00 | 11 | 22.0 | 22.0 | 34.0 |
| 3.00 | 8 | 16.0 | 16.0 | 50.0 |
| 4.00 | 4 | 8.0 | 8.0 | 58.0 |
| 5.00 | 7 | 14.0 | 14.0 | 72.0 |
| 6.00 | 2 | 4.0 | 4.0 | 76.0 |
| 7.00 | 6 | 12.0 | 12.0 | 88.0 |
| 8.00 | 1 | 2.0 | 2.0 | 90.0 |
| 9.00 | 2 | 4.0 | 4.0 | 94.0 |
| 10.00 | 3 | 6.0 | 6.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 4.260 Mode 2.000 Median 3.500 Kurtosis -0.570

Std Dev 2.656 Skewness 0.681 Variance 7.053

Missing Observations 0

VARIABLE — SIZE OF TRACT

TABLE 64

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 5 | 10.0 | 10.0 | 10.0 |
| 2.00 | 26 | 52.0 | 52.0 | 62.0 |
| 3.00 | 10 | 20.0 | 20.0 | 82.0 |
| 4.00 | 4 | 8.0 | 8.0 | 90.0 |
| 5.00 | 2 | 4.0 | 4.0 | 94.0 |
| 6.00 | 2 | 4.0 | 4.0 | 98.0 |
| 10.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 2.700 Mode 2.000 Median 2.269 Kurtosis 7.993

Std Dev 1.568 Skewness 2.463 Variance 2.459

Missing Observations 0

VARIABLE — SLOPE

TABLE 65

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 22 | 44.0 | 44.0 | 44.0 |
| 1.00 | 9 | 18.0 | 18.0 | 62.0 |
| 2.00 | 5 | 10.0 | 10.0 | 72.0 |
| 3.00 | 6 | 12.0 | 12.0 | 84.0 |
| 4.00 | 8 | 16.0 | 16.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.380 Mode 0.0 Median 0.833 Kurtosis -1.139

Std Dev 1.537 Skewness 0.637 Variance 2.363

Missing Observations 0

VARIABLE — LAND COVER

TABLE 66

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 1 | 2.0 | 2.0 | 2.0 |
| 1.00 | 36 | 72.0 | 72.0 | 74.0 |
| 2.00 | 10 | 20.0 | 20.0 | 94.0 |
| 3.00 | 2 | 4.0 | 4.0 | 98.0 |
| 4.00 | 1 | 2.0 | 2.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.320 Mode 1.000 Median 1.167 Kurtosis 3.979

Std Dev 0.683 Skewness 1.835 Variance 0.467

Missing Observations 0

VARIABLE — DRAINAGE

TABLE 67

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 13 | 26.0 | 26.0 | 26.0 |
| 1.00 | 20 | 40.0 | 40.0 | 66.0 |
| 2.00 | 15 | 30.0 | 30.0 | 96.0 |
| 3.00 | 2 | 4.0 | 4.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.120 Mode 1.000 Median 1.100 Kurtosis -0.813

Std Dev 0.849 Skewness 0.176 Variance 0.720

Missing Observations 0

VARIABLE — DENSITY OF ADJACENT DEVELOPMENT

TABLE 68

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 27 | 54.0 | 54.0 | 54.0 |
| 1.00 | 21 | 42.0 | 42.0 | 96.0 |
| 2.00 | 2 | 4.0 | 4.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.500 Mode 0.0 Median 0.0 Kurtosis -0.590

Std Dev 0.580 Skewness 0.633 Variance 0.337

Missing Observations 0

VARIABLE — OBNOXIOUS ADJACENT DEVELOPMENT RATING

TABLE 69

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 4 | 8.0 | 8.0 | 8.0 |
| 1.00 | 15 | 30.0 | 30.0 | 38.0 |
| 2.00 | 23 | 46.0 | 46.0 | 84.0 |
| 3.00 | 5 | 10.0 | 10.0 | 94.0 |
| 4.00 | 3 | 6.0 | 6.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.760 Mode 2.000 Median 1.761 Kurtosis 0.213

Std Dev 0.960 Skewness 0.354 Variance 0.921

Missing Observations 0

VARIABLE -- SCENIC VISTA RATING

TABLE 70

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 50 | 100.0 | 100.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 1.000 Mode 1.000 Median 0.0 Kurtosis 0.0

Std Dev 0.0 Skewness 0.0 Variance 0.0

Missing Observations 0

VARIABLE — CITY WATER

TABLE 71

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 17 | 34.0 | 34.0 | 34.0 |
| 1.00 | 33 | 66.0 | 66.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.660 Mode 1.000 Median 0.0 Kurtosis -1.544

Std Dev 0.479 Skewness -0.676 Variance 0.229

Missing Observations 0

VARIABLE — CITY SEWERAGE

TABLE 72

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 5 | 10.0 | 10.0 | 10.0 |
| 1.00 | 45 | 90.0 | 90.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.900 Mode 1.000 Median 0.0 Kurtosis 5.111

Std Dev 0.303 Skewness -2.667 Variance 0.092

Missing Observations 0

VARIABLE — FIRE PROTECTION

TABLE 73

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 6 | 12.0 | 12.0 | 12.0 |
| 1.00 | 44 | 88.0 | 88.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.880 Mode 1.000 Median 0.0 Kurtosis 3.470

Std Dev 0.328 Skewness -2.339 Variance 0.108

Missing Observations 0

VARIABLE — TRASH COLLECTION

TABLE 74

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj.Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 34 | 68.0 | 68.0 | 68.0 |
| 1.00 | 6 | 32.0 | 32.0 | 100.0 |
| 999.00 | 0 | 0.0 | Missing | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.320 Mode 0.0 Median 0.0 Kurtosis -1.404

Std Dev 0.471 Skewness 0.772 Variance 0.222

Missing Observations 0

VARIABLE — GAS SERVICE

TABLE 75

## Results of the Factor Analysis

Initially eleven factors from the first factor analysis were extracted accounting for 80 percent of the original variance in the data. Variables loading significantly ($>\underline{+}.50$) on each factor are listed below together with the factor score:

| | | |
|---|---|---|
| FACTOR I | SLOPE | .83 |
| | ADJACENT TO ARTERIAL HIGHWAYS | .65 |
| | DRAINAGE | .53 |
| | ADJACENT TO INSTITUTIONAL FACILITY | .51 |
| FACTOR II | DISTANCE TO GREENBELT | .94 |
| | ADJACENT TO COMMERCIAL AREA | -.83 |
| | DISTANCE TO LIMITED ACCESS HIGHWAY | .50 |
| | ADJACENT TO SCHOOL | .66 |
| FACTOR III | ADJACENT TO RESIDENTIAL AREA | .93 |
| | DENSITY OF ADJACENT DEVELOPMENT | .76 |
| FACTOR IV | FIRE PROTECTION | .97 |
| | TRASH COLLECTION | .85 |
| FACTOR V | CITY SEWERAGE | .72 |
| | GAS SERVICE | .63 |

The results of the initial factor analysis proved difficult to interpret. The large number of factors derived and the illogical grouping of some variables indicated problems in the original data array and suggested that some variables lacked enough variance for factor analysis to identify interrelationships. For example, note that most of the compatibility variables (see Tables 54 through 63) had a variance less than 0. To improve the results of the analysis, the compatibility variables were aggregated into two composite variables, reflecting positive attributes of adjacent land parcels and negative attributes. In addition, the variables reflecting the availability of fire protection and trash collection were eliminated also because of lack of variance.

By combining the compatibility variables Tables 76 and 77 were created. Table 76 indicates every residential development event had one or more positive compatibility attributes and over 60 percent of the sample had 3 or more positive compatibility attributes. On the other hand, nearly half of the sample (46 percent) had no negative compatibility attributes, and only 36 percent had one or more (Table 77).

Using the two composite variables in place of the original compatibility variables, the data were factor analyzed a second time. The results of the second factor analysis are found in Table 78. Eight factors were derived, comprised of 19 variables and accounting for 75% of the original variance in the data array. Variables loading on specific factors are listed below:

| | | |
|---|---|---|
| FACTOR I | CITY SEWAGE AVAILABLE | .75 |
| | GAS SERVICE AVAILABLE | .57 |
| | SCENIC VISTA RATING | -.52 |
| | DISTANCE TO RECREATION AREA | -.55 |
| | LOW DENSITY OF ADJACENT DEVELOPMENT | .58 |
| | POSITIVE COMPATIBILITY | .48 |
| FACTOR II | NEGATIVE COMPATIBILITY | .82 |
| | OBNOXIOUS ADJACENT DEVELOPMENT | .56 |
| | DISTANCE TO TRANSPORTATION BARRIER | -.53 |
| FACTOR III | SLOPE | .75 |
| | DRAINAGE | .48 |
| FACTOR IV | DISTANCE TO MAJOR ARTERIAL HIGHWAY | -.76 |
| | DISTANCE TO LIMITED ACCESS HIGHWAY | .57 |
| | SCENIC VISTA RATING | .52 |
| FACTOR V | DISTANCE TO COLLECTOR HIGHWAY | .70 |
| | DISTANCE TO NEAREST SCHOOL | .57 |
| | SIZE OF TRACT | -.56 |
| FACTOR VI | OBNOXIOUS ADJACENT DEVELOPMENT | .72 |
| | DISTANCE TO INSTITUTIONAL USE (OTHER THAN SCHOOL) | .67 |

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 1.00 | 3 | 6.0 | 6.0 | 6.0 |
| 2.00 | 11 | 22.0 | 22.0 | 28.0 |
| 3.00 | 26 | 52.0 | 52.0 | 80.0 |
| 4.00 | 7 | 14.0 | 14.0 | 94.0 |
| 5.00 | 3 | 6.0 | 6.0 | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 2.920  Mode 3.000  Median 2.923  Kurtosis 0.291

Std Dev 0.922  Skewness 0.158  Variance 0.851

Missing Observations 0

VARIABLE — POSITIVE COMPATIBILITY

TABLE 76

| Value | Absolute Frequency | Relative Frequency (Percent) | Adjusted Frequency (Percent) | Cumulative Adj. Freq. (Percent) |
|---|---|---|---|---|
| 0.0 | 23 | 46.0 | 46.0 | 46.0 |
| 1.00 | 18 | 36.0 | 36.0 | 82.0 |
| 2.00 | 9 | 18.0 | 18.0 | 100.0 |
| Total | 50 | 100.0 | 100.0 | 100.0 |

Statistics

Mean 0.720 Mode 0.0 Median 0.611 Kurtosis -1.069

Std Dev 0.757 Skewness 0.508 Variance 0.573

Missing Observations 0

VARIABLE — NEGATIVE COMPATIBILITY

TABLE 77

| | Factors | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Distance to nearest residential area | -0.30 | 0.06 | -0.11 | 0.03 | -0.27 | 0.26 | 0.41 | 0.14 |
| Distance to commercial area | -0.05 | 0.00 | 0.22 | 0.11 | 0.06 | -0.09 | 0.20 | 0.89 |
| Distance to industrial area | -0.21 | -0.05 | 0.09 | -0.02 | 0.27 | 0.10 | 0.58 | 0.22 |
| Distance to institutional use (other than school) | -0.23 | -0.06 | 0.29 | -0.11 | 0.19 | 0.67 | 0.10 | -0.03 |
| Distance to recreation area | -0.55 | 0.22 | -0.28 | -0.24 | 0.39 | -0.05 | 0.15 | 0.31 |
| Distance to nearest school | -0.26 | -0.10 | -0.35 | 0.09 | 0.58 | 0.09 | 0.28 | 0.20 |
| Distance to transportation barrier | 0.01 | -0.53 | -0.23 | 0.14 | -0.09 | -0.06 | -0.59 | 0.19 |
| Distance to limited access highway | -0.02 | -0.16 | 0.02 | 0.57 | -0.06 | 0.08 | -0.21 | 0.09 |
| Distance to major arterial highway | -0.17 | -0.35 | 0.08 | -0.77 | -0.14 | 0.20 | -0.09 | 0.00 |
| Distance to collector highway | -0.16 | 0.29 | -0.00 | 0.08 | 0.70 | 0.01 | -0.05 | -0.18 |
| Positive compatibility | 0.49 | -0.18 | 0.20 | 0.27 | -0.41 | -0.04 | 0.08 | -0.18 |
| Negative compatibility | 0.05 | 0.82 | 0.05 | 0.02 | 0.03 | 0.03 | 0.06 | 0.06 |
| Size of tract | -0.20 | 0.14 | -0.16 | -0.01 | -0.56 | -0.21 | 0.10 | -0.14 |
| Slope | -0.02 | 0.29 | 0.75 | 0.02 | -0.08 | 0.13 | 0.14 | 0.04 |
| Land cover | 0.04 | 0.01 | 0.08 | -0.04 | -0.08 | -0.06 | 0.31 | 0.04 |
| Drainage | 0.11 | -0.07 | 0.49 | 0.02 | 0.03 | 0.09 | 0.11 | 0.14 |
| Density of adjacent development | 0.59 | -0.11 | -0.05 | 0.04 | 0.01 | 0.20 | -0.19 | -0.10 |
| Obnoxious adjacent development rating | 0.25 | 0.57 | 0.09 | 0.05 | 0.11 | 0.73 | -0.13 | -0.16 |
| Scenic vista rating | -0.52 | -0.04 | 0.39 | 0.52 | 0.11 | -0.01 | 0.01 | -0.00 |
| City sewerage | 0.76 | 0.11 | 0.03 | -0.06 | -0.02 | -0.28 | 0.11 | 0.01 |
| Gas service | 0.58 | 0.19 | 0.09 | -0.01 | -0.01 | -0.03 | -0.06 | 0.09 |

VARIMAX ROTATED FACTOR MATRIX

TABLE 78

FACTOR VII DISTANCE TO TRANSPORTATION BARRIER -.59
LAND COVER .58

FACTOR VIII DISTANCE TO COMMERCIAL AREA .89

Several improvements can be noted immediately when comparing the second factor analysis with the initial results: Note, Factor I is composed of the good attributes of residential development, while Factor II generally reflects the bad characteristics associated with a development site. Note also the variables identified as significant in the previous factor analysis are still present but have shifted in rank. Topographic suitability is now alone as Factor III while accessibility to services and highways is spread among the remaining factors. The lack of any clear relationship among some variables in Factors V, VI, and VII is thought to be the result of a limited sample and perhaps the unique land use characteristics associated with the East Tennessee region. This would include variables such as scenic vista rating (Factor I and Factor IV), size of tract (Factor V), and land cover (Factor VII).

In general the results of the analysis agree with literature and intuitive assumptions as to the factors influencing residential location decisions. Before structuring a site selection algorithm addition, analysis should be conducted including a larger sample and, perhaps, refinement of some variables. The final section discusses the conclusions drawn from the industrial and the residential land use analyses.

# VI. SUMMARY AND CONCLUSIONS

## Summary

The objectives of this research effort represent a portion of a much larger research objective, the identification of the determinants affecting land use change. Because land use change is the result of a complex process, it was decided to focus upon two aspects of the problem, the conversion of land to industrial use and conversion to residential use. The approach assumes the determinants of this conversion process are found in the "market place," where land transactions among buyers and sellers occur. Research was directed, however, toward one side of the market transaction process, namely that of the purchaser's desires in securing an ideal or suitable site. The problem was to identify the ideal qualities, quantities or attributes desired in specific sites which might permit the identification of potential industrial and residential sites.

Research procedures focused upon developing a list of variables previously noted to be related to industrial and residential site selection from the literature and streamlining the list to a set suitable for statistical testing. Measurements of relevant variables were obtained for a sample of industries locating (or relocating) in the 16-county Knoxville metropolitan region in the period from 1950 to the present. These data were subjected to factor analysis to determine interrelations of variables, to minimize the list of variables needed to describe the

industrial site-selection process, and to determine if the preconceived ideas concerning the factors affecting the process were valid. Seven factors accounting for 72 percent of the variance found in the original data were identified. The results suggest that a planned, designated place for industry to locate and accessibility to the site are the two most important considerations in industrial site-selection decisions.

A sample of 50 residential development events occurring in the Knoxville Metropolitan area was selected for the residential land use analysis. Using variables noted by other investigators as being related to the process, measurements were compiled for each residential development. Factor analysis was utilized to reduce the number of variables and uncover hidden interrelationships in the data. Eight factors accounting for 75 percent of the original variance were derived. The results suggest availability of municipal services, positive compatibility to adjacent land uses, absence of negative compatibility, topographic suitability, and accessibility to transportation services are the most important considerations in single-family residential developments.

## Conclusions

The general objectives of this research effort have been accomplished. Although it would be desirable to conclude with specific mathematical statements describing the industrial and residential site-selection processes, it is not possible without the refinement of the analysis to include more observations and, perhaps, the inclusion of additional variables. The following conclusions, however, have been determined.

Conclusions Regarding the Form of Site-Selection Algorithms

The 27 variables examined in the industrial analysis did not group as previously conceived but nevertheless the factors present a logical arrangement of variables. Factors II, IV, VI, and VII are almost singularly identified by accessibility. Reexamination of the accessibility factors indicates they could be combined, thereby reducing the number of idexes to two or three. Apparently, each accessibility variable possesses distinct qualities not common with others. However, this does not mean they could not be combined into a single index. To compensate for the greater importance of specific accessibility variables, weights derived from the factor-score coefficient (or factor estimate) matrix might be used in a site-selection algorithm. (Values derived from the factor estimate matrix reflect the relative importance of each variable to the factor identified and are commonly used to build composite indexes.) From this analysis four indexes are identified: (1) a protected or planned area for industrial development; (2) space for industry to develop; (3) accessibility to transportation media; and (4) site preparation costs.

The 33 variables utilized in the residential land use analysis were reduced to 19 as a result of the factor analysis. Although clear indexes were not revealed by the factor analysis, use of the 19 variables in a simulation algorithm is clearly desirable due to the percent of variance for which they account (75 percent). Additional study with a larger sample should provide more insight as to the proper form of the algorithm but some major components of the algorithm are indicated.

Availability of municipal services (water, sewage, etc.) at potential development sites appears to be a strong determinant for residential land use. Secondly, land uses adjacent to the site should be highly compatible to residential land uses. Finally, the proximity of the potential site to a major thoroughfare such as an interstate is also indicated as important to the location decision.

These conclusions, obviously, are not unexpected and probably could be derived independent of the factor analyses by subjective methods. By assigning the weights derived by use of factor-score correlation matrix, however, it is possible to construct a weighted linear algorithm reflecting the potential of a given parcel of land for residential development. A test of this approach should be conducted.

Conclusions Regarding Model Operation

As suggested, additional research would produce more complete approximation of the algorithms suitable for simulating a site-selection process. The factors identified in this study, however, suggest major components of the algorithms. There is some question as to whether it would be possible to develop an optimal algorithm because it is doubtful that we will ever be able to predict individual location events. Selection of suitable sites ultimately should be accomplished through stochastic simulation procedures which capitalize upon average events. The algorithm previously suggested in the Introduction utilizes a linear summation of indexes and easily lends itself to stochastic procedures. The higher the suitability score, the greater the probability for development. This study demonstrates a way in which parameters relevant to the location

process can be factored into the algorithm and the suitability scores calculated.

Conclusions Regarding Use of Aerial Photography in Model Design

A primary objective of this analysis was that of demonstrating the utility of aerial photography in compiling land use data and determining measurements on relevant variables. A major initial problem in analyzing site-selection processes is finding the site and measuring specific variables. Aerial photography was found to be most useful for locating industries and compiling measurements; and, consequently, reduced field work time considerably. In using aerial photography for the residential analysis, it was found that little ground truth was necessary. Topographic maps were utilized when necessary to position sites relative to churches, schools, etc., but little other information was necessary. It is possible that the entire data collection can be accomplished through the use of photography but it would be wasteful not to capitalize upon extant data sources normally found in planning offices.

The imagery utilized in this study was provided by NASA-Marshall Space Flight Center in Huntsville, Alabama, and flown at a scale of 1:24,000. This permitted superimposition directly onto 1:24,000 TVA topographic maps and greatly simplified the locational analysis. The determination of neighborhood quality characteristics, slope characteristics, accessibility characteristics, and size of the site was almost completely evaluated via air photo interpretation.

It should be stressed that the use of aerial photography was not a panacean solution to data acquisition problems. Field work and ground-truth surveys are certainly necessary. Analyses of this type, however, can benefit greatly from the use of aerial photography and planning agencies should be encouraged to put aerial photography to more rigorous use.

Conclusions Regarding Recommendations for Future Research

The data collection and analysis procedures utilized in this research task have been proven to be useful in understanding two broad types of land conversion processes. There is no reason that similar procedures might not be applied toward analyzing commercial land use development processes and other specific land use conversion processes.

Future research objectives should include variations of the factor analysis procedures to group industries having similar locational preference rather than grouping variables. In addition, insight acquired in this study suggests that the locational criteria are regionally dependent such that differing location parameters may become important in other metropolitan regions. The procedures utilized in this study lend themselves to a regional type of analysis.

Some of the results obtained in this study suggest investigating dimensions of suitability, accessibility, and compatibility which best discriminate among residential, commercial, and industrial land development patterns. The disparity between the components of industrial development and the components of residential development found here imply that

commercial developers and residential developers use quite different cognitive processes in evaluating site potential. Quantitative statements regarding the probable development patterns of a region based on site factors which may be inferred with remote sensing techniques would be of value to planners in developing alternative futures and evaluating development policy.

Finally, this conclusion is emphasized: <u>the procedures developed and utilized in this research have a variety of potential applications to land use location analysis problems and permit one to calibrate and validate land use modeling algorithms.</u>

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# APPENDIX A

## SAMPLE SURVEY FORM

SAMPLE SURVEY FORM

Latitude________________ Longitude________________

Industry Name______________________________________________

ORNL Industry No.______________ Date of Entry__________________

SIC No.__________________________ Quadrangle__________________

County_______________________________ Employment Beginning______

City_________________________________ Employment Now___________

| | |
|---|---|
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Slope of land |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Drainage |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Clearing-cover conditions |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to center of town |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest major throughfare |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Density of land use in immediate vicinity |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Rating of price of land |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Percent of urban area within 2-1/2 miles |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to major highway |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to secondary road |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to railway |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to airport |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to waterway |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest Interstate |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Overall quality of accessibility (then) |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Overall quality of accessibility (now) |

| | |
|---|---|
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | City water availability |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Gas availability |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | City sewage availability |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Was it zoned for industry? |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Was industry already in area? |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Overall rating of contiguous land use |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Condition of neighborhood |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Nearby community services |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Was the site in an industrial park? |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | What was the quality of the site? |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Proximity to Knoxville |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Amount of other industry located nearby |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Was a building already there? |

RESIDENTIAL SURVEY FORM

| | |
|---|---|
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest residential area<br>1 = adjacent 5 = 1 mile 10 = 2 miles or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest commercial area<br>1 = adjacent 5 = 1 mile 10 = 2 miles or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest industrial area<br>1 = adjacent 5 = 1 mile 10 = 2 miles or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest institutional use other than school<br>1 = adjacent 5 = 1 mile 10 = 2 miles or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest recreation area<br>1 = adjacent 5 = 1 mile 10 = 2 miles or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest school<br>1 = adjacent 5 = 1 mile 10 = 2 miles or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest transportation barrier (rail, interstate, etc.)<br>1 = adjacent 10 = 2 miles or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest greenbelt or water body<br>1 = adjacent 5 = 1 mile 10 = 2 miles or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest limited access highway<br>1 = adjacent 5 = 1 mile 10 = 2 miles or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to nearest major urban arterial highway<br>1 = adjacent 5 = 1 mile 10 = 2 miles or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Distance to collector highway<br>1 = adjacent 5 = 1 mile 10 = 2 miles or more |
| 0, 1, 2, 3, 4 | Adjacent to residential area<br>0 - 4 number of sites |

| | |
|---|---|
| 0, 1, 2, 3, 4 | Adjacent to commercial area<br>0 - 4 number of miles |
| 0, 1, 2, 3, 4 | Adjacent to industrial area 0 - 4 |
| 0, 1, 2, 3, 4 | Adjacent to institutional facility 0 - 4 |
| 0, 1, 2, 3, 4 | Adjacent to recreational facility 0 - 4 |
| 0, 1, 2, 3, 4 | Adjacent to school 0 - 4 |
| 0, 1, 2, 3, 4 | Adjacent to transportation barrier 0 - 4 |
| 0, 1, 2, 3, 4 | Adjacent to greenbelt or water body 0 - 4 |
| 0, 1, 2, 3, 4 | Adjacent to arterial highway 0 - 4 |
| 0, 1, 2, 3, 4 | Adjacent to collector highway 0 - 4 |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Size of tract 1 = <10 acres 5 = 50 acres<br>10 = 100 acres or more |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Slope of land 1 = flat 5 = 10% slope<br>10 = 20% or more |
| 0, 1, 2, 3, 4 | Land cover 0 = no cover 4 = forested |
| 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 | Drainage 1 = well drained 10 = subject<br>to flooding |
| 0, 1, 2, 3, 4 | Density of adjacent development<br>0 = open all sides 4 = developed all sides |
| 0, 1, 2, 3, 4 | Obnoxious adjacent development rating<br>0 = equal or better all four<br>4 = % obnoxious on all four sides |
| 0, 1, 2, 3, 4 | Scenic vista rating 0 = total lack of<br>scenery 4 = scenic optimal |
| 0, 1 | City water 0 = no 1 = yes |
| 0, 1 | City sewage 0 = no 1 = yes |
| 0, 1 | Fire protection 0 = no 1 = yes |
| 0, 1 | Trash collection 0 = no 1 = yes |
| 0, 1 | Gas service 0 = no 1 = yes |